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NASA/MSFC FY-85 Atmospheric Processes Research Review

*Compiled by
William W. Vaughan and Fay Porter
George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama*

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INTRODUCTION

Each year NASA supports research in various disciplinary program areas. The coordination and exchange of information among those sponsored by NASA are important elements of each program. The Office of Space Science and Applications, Earth Science and Applications Division, via Announcements of Opportunity (AO), Application Notices (AN), etc., invites interested investigators throughout the country to communicate their research ideas for consideration. The proposals in the Atmospheric Processes Research area selected and assigned to the NASA Marshall Space Flight Center's (MSFC's) Atmospheric Sciences Division for technical monitorship, together with the research efforts included in the MSFC Research and Technology Operating Plan (RTOP), are the source of principal focus for the NASA/MSFC FY-85 Atmospheric Processes Research Program Review.

The principal purpose of the review and summary report is to provide those having atmospheric research activities sponsored by NASA, and assigned to MSFC's Atmospheric Sciences Division, an opportunity to communicate their accomplishments and future plans. In addition, the review provides NASA Headquarters and MSFC Research Program Managers with a current status report plus suggestions for future research to use in developing the program. The principal managers involved are Dr. John Theon, Dr. James Dodge, and Dr. Robert Curran, Atmospheric Dynamics and Radiation Branch, Earth Science and Applications Division, OSSA, and Dr. William W. Vaughan, Dr. George Fichtl and Dr. Gregory Wilson, Atmospheric Sciences Division, Systems Dynamics Laboratory, MSFC. Ms. Fay Porter served as coordinator for the preparation of the MSFC research review reports.

The two main areas of focus for NASA/MSFC's Atmospheric Research Program are: (1) Global Scale Processes (Geophysical Fluid Processes, Satellite Doppler Lidar Wind Profiler, and Satellite Data Analyses), and (2) Mesoscale Processes [Atmospheric Electricity (Lightning), Ground/Airborne Doppler Lidar Wind Measurements, and Mesoscale Analyses and Space Sensors].

It is recognized that the scopes of individual research efforts comprise a wide range. Some are very modest or have been underway for only a short period of time, whereas others are relatively large and involve several years of activity. However, the opportunity to learn what each investigator is doing and to develop the team relationship necessary for a meaningful research program were considered most important. The technical aspects of the research efforts are stressed with respect to accomplishments and rationale for the recommendations on the coming year's research. It is toward this goal that this summary report has been developed.

Recipients of this report are encouraged to communicate directly with the respective investigators regarding scientific and technical matters or questions they might have on the research efforts. Any recommendations or suggestions concerning the program will be welcomed.

GEOPHYSICAL FLUID PROCESSES

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TITLE: Theoretical and Experimental Studies of Baroclinic Processes

INVESTIGATORS: Dr. Tim Miller
Dr. Fred Leslie
Dr. Dan Fitzjarrald
Atmospheric Sciences Division
Marshall Space Flight Center
(205) 453-2087

Mr. Nathaniel Reynolds
USRA Visiting Scientist
Marshall Space Flight Center

SIGNIFICANT ACCOMPLISHMENTS:

(1) An experimental study in a baroclinic annulus with heating and cooling on the upper and lower horizontal surfaces was completed. Four basic regimes of flow were observed: (1) axisymmetric flow, (2) cellular (deep) convection, (3) convective rolls (boundary layer), and (4) baroclinic instability. There was no symmetric (or nearly symmetric) baroclinic instability observed, although it was determined by numerical calculations that we transversed regions in parameter space where the symmetric instability was present. The non-symmetric baroclinic instability (Eady type) was observed instead. Although the vertical depth was rather small and hence viscous damping was strong, large-amplitude baroclinic waves were made possible by imposing a very weak static stability.

(2) A linear analysis of symmetric baroclinic instability was completed, and a journal article was accepted for publication. The analysis covered the range from non-hydrostatic through strongly hydrostatic (i.e., from weakly baroclinic through strongly baroclinic) cases. The dependence of the critical Richardson number (Ri) upon baroclinicity, Ekman number, and Prandtl number was elucidated. The energy conversion mechanisms were shown to have considerable variation, depending upon the parameters.

(3) A linear analysis of three-dimensional, non-geostrophic baroclinic instability was completed, and a journal article has been submitted for publication. It was shown that, when finite viscosity is present, the preferred angle of orientation (for small enough Ri) is not the symmetric angle, regardless of Prandtl number. This contrasts with the classical inviscid analysis of Stone. The enhancement of the instability by allowing the angle to be free is significant, especially as the wavelength increases from the critical symmetric value.

RESEARCH OBJECTIVES:

Our objective is to further the understanding of baroclinic processes in the atmosphere. We are especially interested in the possible interaction and/or co-existence of phenomena of varying spatial scales.

CURRENT RESEARCH:

(1) Mr. Nathaniel Reynolds of Florida State University is finishing his graduate work as a USRA Visiting Scientist at MSFC. His work involves a

fully nonlinear two-layer quasi-geostrophic model with topographical forcing of planetary scale. This work will help elucidate the interactions between planetary scale waves and synoptic scale baroclinic waves.

(2) A baroclinic annulus with conducting lower surface and insulating top and sides is under construction. This apparatus will enable us to examine baroclinic instability in a configuration whose conductive state temperature field is qualitatively similar to the atmosphere's radiative state. We expect that there will be interesting interaction between small-scale convective instabilities and baroclinic instabilities in the warm part of the flow cell.

(3) A fully nonlinear, three-dimensional, primitive equations computer code is being developed. When operative, this code will enable us to examine the interaction of modes of different scales and their effects upon the mean state. One question to be addressed is the extent that a synoptic scale baroclinic wave can "create" a smaller scale region of instability of the symmetric and almost symmetric modes.

FUTURE PLANS:

Besides the continuation of the present work, future plans include the following:

(1) Determination of the extent to which purely analytical methods can be applied to the planetary scale/synoptic scale interaction problem of Mr. Reynolds' dissertation.

(2) Investigation of the worthiness of building other laboratory models of baroclinic processes. For example, this might include a spherical experiment in space.

(3) Further development of the "channel" models of the P.I. (see references) to include more atmospheric effects, such as latent heating and/or more realistic boundary conditions.

(4) Development of fully three-dimensional, nonlinear numerical models of the laboratory experiments.

REFERENCES:

1. Miller, T. L., 1984: The structures and energetics of fully nonlinear symmetric baroclinic waves. *J. Fluid Mech.*, Vol. 142, pp. 343-362.
2. Miller, T. L., 1985: On the energetics and non-hydrostatic aspects of symmetric baroclinic instability. *J. Atmos. Sci.*, Vol. 42, No. 2 (in press).
3. Miller, T. L., and B. N. Antar, 1985: On viscous non-geostrophic baroclinic instability. Submitted.
4. Miller, T. L., and W. W. Fowlis, 1985: Laboratory experiments in baroclinic instability with heating and cooling on the horizontal boundaries. In preparation.

N86-15771

TITLE: Mobile Intercept of Storms

INVESTIGATOR: Dr. Roy T. Arnold
University of Mississippi
University, MS 38677
(601) 232-5402

SIGNIFICANT ACCOMPLISHMENTS IN FY-85:

A major portion of our effort during FY-85 was participation in the field program with a NASA U2 research aircraft flying over storms in the area of Oklahoma, southern Kansas, and north Texas. Our primary goal was to acquire lightning data to serve as ground truth for U2 overflights. We were successful in instrumenting the UM/NSSL mobile laboratory (designated UN/NSSL because of the collaborative effort with the National Severe Storms Laboratory) and in coordinating our storm intercept through communication to the U2 provided by airplane guidance at NSSL and through direct communication with the U2 pilot from a portable transceiver in the mobile lab. The season was successful in spite of a number of events out of our control, including a general and unusual sparsity of storm activity during the operational period and an early termination of the scheduled flight program. Included in the success was a demonstration that a mobile laboratory can be directed within a large geographical area and used to collect ground truth data for comparison with airborne data on a routine basis with proper utilization of forecasts, nowcasts, and communication among all participants.

After the U2 flights, we turned our attention solely to intercepting severe storms within the area of Oklahoma with good Doppler radar coverage. We incorporated a second vehicle, which followed the mobile lab and from which we released instrumented balloons. This project, in collaboration with Dr. Tom Marshall of the University of Mississippi, utilized a standard meteorological rawinsonde and a balloon-borne electric field meter. We were successful in flying, tracking, and receiving data from mobility launched balloons on several days. We believe that we have demonstrated the ability to obtain meteorological and electrical data in severe storms using instrumented balloons. This also includes the capability to launch into the mesocyclone region and for multiple launches in the same storm.

FOCUS OF CURRENT RESEARCH ACTIVITIES:

Currently we are analyzing previously obtained data. The mobile laboratory has been sent to NSSL where it is part of their effort to acquire lightning data on severe storms and mesoscale convective systems.

PLANS FOR FY-86:

At present we are evaluating future work in light of our existing personnel available. At this time we do not have funding or a proposal for additional funding for consideration within NASA. We feel that the techniques established and results obtained with the mobile laboratory fully demonstrate its ability and in fact its importance for acquiring in situ information on storms that form and move within large areas.

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PUBLICATIONS SINCE JUNE 1984:

Lightning and Related Phenomena in Isolated Thunderstorms and Squall Line Systems. W. D. Rust, W. L. Taylor, D. R. MacGorman, E. Brandes, V. Mazur, R. Arnold, T. Marshall, H. Christian, and S. J. Goodman. J. of Aircraft, to be published, May 1985.

Screening Layers at the Surface of Thunderstorm Anvils. T. C. Marshall, W. D. Rust, and W. P. Winn. Preprints, pp. 246-247, 7th Intl. Conf. on Atmos. Elec., Albany, New York, June 4-8, 1984.

Some Characteristics of Lightning in Severe Storms on the Great Plains of the United States. D. R. MacGorman, W. L. Taylor, W. D. Rust, and R. T. Arnold. Preprints, pp. 299-304, 7th Int. Conf. on Atmos. Elec., Albany, New York, June 4-8, 1984.

Simultaneous Observations of Cloud-to-Ground Lightning Above and Below Cloud Tops. S. J. Goodman, H. J. Christian, W. D. Rust, D. R. MacGorman, and R. T. Arnold. Preprints, pp. 456-462, 7th Intl. Conf. on Atmos. Elec., Albany, New York, June 4-8, 1984.

Site Errors in a Lightning Strike Locating System in Oklahoma. D. M. Mach, D. R. MacGorman, W. D. Rust, and R. T. Arnold. Abstract, Eos, Vol. 65, p. 842, 1984.

Calculating Stepped Leader Velocities of Lightning in Severe Storms. S. Horsburgh. Abstract, Eos, Vol. 65, p. 841, 1984.

TITLE: Theoretical and Experimental Studies in Support of the Geophysical Fluid Flow Experiment

INVESTIGATORS: John Hart and Juri Toomre
 Department of Astrophysical, Planetary and
 Atmospheric Sciences
 University of Colorado
 Boulder, Colorado 80309
 (303) 492-8568
 (303) 492-7854

FOCUS OF CURRENT RESEARCH ACTIVITIES:

Meteorologists and astrophysicists interested in large scale planetary and solar circulations have come to recognize the importance of rotation and stratification in determining the character of these flows. In particular, the effect of latitude-dependent Coriolis force on nonlinear convection is thought to play a crucial role in such phenomena as differential rotation on the Sun, cloud band orientation on Jupiter, and the generation of magnetic fields in thermally driven dynamos. Most theoretical and all experimental work on these problems has in the past treated only local curvature effects — the mid-latitude or equatorial β -planes of meteorology being well-known examples. In fact, terrestrial laboratory experiments have only been able to study β -plane flows in situations where the stratification is extremely simple, usually two layers of fluid of slightly different density. The continuous low-gravity environment of the orbiting space shuttle offers a unique opportunity to make laboratory studies of such large-scale thermally driven flows under the constraint imposed by rotation and sphericity. This is possible because polarization forces in a dielectric liquid, which are linearly dependent on fluid temperature, give rise to an effectively radial buoyancy force when a radial electrostatic field is imposed. The Geophysical Fluid Flow Cell (GFFC) is an implementation of this ideal in which fluid is contained between two rotating hemispheres that are differentially heated and stressed with a large a-c voltage. The experiment, to be flown on Spacelab III (currently set for launch April 29, 1985), will explore nonlinear mode selection and high Rayleigh number turbulence in a rotating convecting spherical shell of liquid. Experiments will be carried out in a low driving parameter range where some limited numerical experimentation is currently feasible, as well as in a parameter range significantly beyond numerical computation for many years. Our group has developed a data analysis system, and has been working on several theoretical, numerical, and (terrestrial) laboratory problems which model certain aspects of the expected GFFC motions.

RESEARCH ACCOMPLISHMENTS, JUNE 84 TO APRIL 85:

A. GFFC Data Analysis.

Data from the GFFC consist of thermal and dye-line images, and decimal and binary LED registers, all recorded on 16 mm film. These images will be read by a digitally addressible TV. Software and hardware were completed which allow "rapid" (2 sec/frame) conversion of the film images to disc files. Further programs will do such things as coordinate

transformations, calibrations, removal of optical irregularities on the experiment spheres directly using the raster scan image, and decoding the LED dot matrix (binary) data at the frame edges.

B. Laboratory Studies.

Several laboratory studies of convection were complete. A period doubling cascade to turbulence was observed in low Prandtl number Hadley circulations. This is replaced by a quasi-periodic route at higher Prandtl number. These terrestrial laboratory Hadley cells are analogous to those expected in the GFFC when the inner sphere has an imposed temperature gradient and the rotation period is very low.

C. Theoretical Studies.

Further modeling of the bifurcation sets in single and double-diffusive fluid loops was carried out. A new form of relaxation oscillation was found. Information about the previous pulse is communicated to the next one via a long diffusive tail. Thus complex oscillations occurring over many cycles are possible, and under certain conditions the model system exhibits sensitive dependence on initial conditions (chaos).

D. Numerical Studies.

An efficient spectral code for integrating the full three dimensional electro-hydrodynamic equations in the GFFC geometry was completed by Gary Glatzmaier. Several runs were made to guide scenario selection and possible flight reprogramming. We are currently using diagnostic techniques to explore various questions about the underlying dynamics of these solutions.

Toomre and colleagues (see references) completed several studies of compressible convection. Of particular interest for applications of the GFFC results to astrophysical objects is the increasing asymmetry in convection as the fluid becomes more and more non-Boussinesq. Such asymmetries arise because pressure fluctuations accentuate buoyancy driving in the concentrated downward flowing plumes and can lead to buoyancy braking in the ascending flows.

E. Instrument Support.

Throughout this period numerous tasks concerned with the GFFC instrument were performed. In summary, an operational instrument was delivered to the cape for integration and eventual (currently scheduled for April 29, 1985) launch on Spacelab II.

PLANS FOR MAY 85 TO OCTOBER 85:

A. Analyze GFFC Data Films.

After the Spacelab III mission, the following activities will occupy the brunt of our research time.

(1) Digitize the diode encoded data on the approximately 40,000 frames of GFFC images. Store these data in a database so that the performance of the instrument may be quickly evaluated by comparing the measured values (rotation period, temperatures on bounding surfaces, etc.) with those commanded for the various scenarios run during the mission.

(2) Raster scan (192 x 192) the central images of all the data and file on tape. For the thermal data, remove the bias and (as best we can) remove the anomalous data caused by aberrations in the GFFC optical train. For the dye lines, make a second pass to identify dye positions and file as a set of curves.

(3) Produce a quick look report on the operational performance of the GFFC instrument and on the preliminary science results. These latter shall include initial comparisons with linear stability theory and numerical simulations at the more modest Rayleigh numbers where computational convergence is most easily attained.

(4) Analyze in depth the wavenumber selection processes and zonal influence (differential rotation). In this task (which will take the most time of those listed) extensive use of numerical and (terrestrial) laboratory modeling will be made.

B. Continue theoretical, laboratory, and numerical modeling of convective flows.

PAPERS PUBLISHED OR SUBMITTED (Wholly or Partially Supported by
NAS-8-31958)

Hart, J.: A new analysis of the closed loop thermosyphon. Int. J. Heat and Mass Transfer, Vol. 27, pp. 125-136, 1984.

Hart, J.: Observations of complex oscillation in a differentially heated tube. J. Heat Transfer, in press, 1985.

Hart, J.: On the circulation of the loop thermosyphon including the Soret effect. J. Heat Transfer, in press, 1985.

Hurlburt, N. E., J. Toomre, and J. M. Massaguer: Two-dimensional compressible convection extending over multiple scale heights. The Astrophysical Journal, Vol. 282, pp. 557-573, 1984.

Massaguer, J. M., J. Latour, J. Toomre, and J.-P. Zahn: Penetrative cellular convection in a stratified atmosphere. Astronomy and Astrophysics, Vol. 140, p. 1-16, 1984.

Toomre, J., N. E. Hurlburt, and J. M. Massaguer, Strong downward plumes resulting from compressibility in nonlinear convection and their coupling to gravity waves. Proc. Small Scale Dynamical Processes in Quiet Stellar Atmospheres, Nat. Solar Observatory, pp. 222-234, 1984.

TITLE: Theoretical and Experimental Design Studies for the Atmospheric General Circulation Experiment

INVESTIGATORS: William W. Fowlis and David H. Hathaway (ES52)
Space Science Laboratory, ES73
NASA Marshall Space Flight Center
Huntsville, AL 35812
(205) 453-5508
(205) 453-0118

Timothy L. Miller
Systems Dynamics Laboratory, ED42
NASA Marshall Space Flight Center
Huntsville, AL 35812
(205) 453-3104

Glyn O. Roberts
Roberts Associates, Inc.
Vienna, VA 22180
(703) 938-1757

Kenneth J. Kopecky
Dept. of Mathematics & Computer Science
Drake University
Des Moines, IA 50311
(515) 271-2118

SIGNIFICANT ACCOMPLISHMENTS IN FY-85:

The major criterion for the AGCE design is that it be possible to realize strong baroclinic instability in the spherical configuration chosen. In previous years, numerical codes were developed to determine the two-dimensional, nonlinear, basic states and to examine the linear stability of these basic states to azimuthal perturbations. These codes are used to determine the baroclinically unstable region and, hence, prepare regime diagrams for selected AGCE configurations. A regime diagram for a hemispherical shell configuration with heating at the equatorial plane, cooling at a high latitude boundary and insulating spherical boundaries was previously determined.

During the past year, another configuration was selected for the stability studies. In this configuration, a hemispherical shell of fluid is subjected to latitudinal temperature gradients on its spherical boundaries and the latitudinal boundaries are insulators. Work in the laboratory with a cylindrical version of this configuration revealed more instabilities than baroclinic instability. Since we fully expect these additional instabilities to appear in the spherical configuration also, we decided to continue the laboratory cylindrical annulus studies. Four flow regimes have been identified, namely, an axisymmetric Hadley circulation, boundary layer convection, baroclinic waves and deep thermal convection and regime diagrams have been prepared.

FOCUS OF CURRENT RESEARCH ACTIVITIES:

We had originally hoped to find a dielectric liquid which would enable us to achieve a value for the simulated radial dielectric gravity close to terrestrial gravity and the previous regime diagrams were calculated using $g_E = 980 \text{ cm/s}^2$. A systematic and thorough search revealed that no such liquids exist, and, hence, we must make do with values between 0.1 g and 0.25 g. Numerical computations are now being performed at lower values of radial gravity for locations in parameter space where strong baroclinic instability was found previously. Preliminary results indicate that baroclinic instability is still present.

Since gravity has to be reduced, the ratio of centrifugal force to gravity will increase and any consequences of this change should be examined. The computer codes will be run with centrifugal force included and these computations will begin soon.

PLANS FOR FY-86:

The work is being carried out with FY-84 funds and some of the final efforts may not be completed until early in FY-86.

PUBLICATIONS SINCE JUNE 1984:

Laboratory Experiments in A Baroclinic Annulus With Heating and Cooling on the Horizontal Boundaries. T. L. Miller and W. W. Fowlis. Submitted to Geophysical and Astrophysical Fluid Dynamics, April 1985.

Flow Regimes in a Shallow Rotating Cylindrical Annulus With Temperature Gradients on the Plane Horizontal Endwalls. D. H. Hathaway and W. W. Fowlis. In preparation.

SATELLITE DOPPLER LIDAR

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TITLE: Multiscale Modeling to Evaluate Proposed Space-Based Doppler Lidar Sampling Strategies

INVESTIGATOR: G. D. Emmitt
Simpson Weather Associates, Inc.
Charlottesville, Virginia 22902

SIGNIFICANT ACCOMPLISHMENTS:

Doppler lidars have a demonstrated capability to measure the line-of-sight component of the winds at ranges up to a few tens of kilometers. Ground based CW (Kopp, et al., 1984) and pulsed (Huffaker and Hall, 1982) lidars have been used to obtain estimates of the three wind components by conically scanning about a vertical axis. Airborne pulsed lidars (Bilbro, et al., 1984; Emmitt, 1985) have produced two-dimensional maps of the horizontal winds in a manner similar to dual Doppler radar except that the aircraft motion is used to obtain two perspectives on the target volume. A proposal has been made to place a pulsed Doppler lidar on a space platform (Huffaker, et al., 1980; Emmitt, 1982) in a low earth orbit (200 to 800 km) to measure the atmospheric winds with a spatial resolution commensurate with the current continental rawinsonde network density — i.e., 300 to 500 km resolution.

The ground, aircraft and satellite based lidar wind sensing systems have in common a cylindrical sample volume with a diameter of 10^{-1} to 10^1 meters and a length of 10^1 to 10^3 meters. However, the areas over which single wind estimates are made range from 10^2 (ground-based CW and airborne pulsed) to 10^4 (ground-based pulsed) to 10^6 meters for satellite-based pulsed lidar. Furthermore, the manner in which the individual "shots" of radial wind information are combined to estimate a 2 or 3-dimensional wind vector varies significantly between ground-based, airborne, and space-based operations.

In the case of the space-based Doppler lidar, the full range of space scales applies. Single shot pulses with dimensions of $10^1 \times 10^3$ meters are used to sample areas $10^5 \times 10^5$ meters to resolved mass flow structure with wavelength of 10^6 meters. Simulation studies, therefore, require an equally broad range of atmospheric models. A general circulation model is appropriate to answer questions regarding the impact of a global wind measuring system upon synoptic forecasts. Since the nominal resolution of the space-based system is expected to be a few 100's of kilometers, then a numerical model with mesoscale dynamics is required. The meaning of an average Doppler shift within a laser pulse volume must be evaluated with models of turbulent/convective scale motions and aerosol gradients.

Examples of how models on all these scales have been applied in an ongoing simulation study will be presented. In particular, the uncertainties in a mesoscale wind estimate will be separated into those arising from pulse scale variances and those due to sample distribution within a prescribed resolution volume. Trade-offs between accuracy and representativeness will be discussed in terms of the model results.

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- Emmitt, G. D., 1982: Conical Lidar Scanning from LEO—The Effects of Meso β and Convective Scale Atmospheric Phenomena. Abstracts of the Eleventh International Laser Radar Conference, NASA Conf. Pub. 2228, Madison, WI.
- Emmitt, G. D., 1985: Convective Storm Downdraft Outflows Detected by NASA/MSFC's Airborne 10.6 μ m pulsed Doppler Lidar System. Submitted as a contractor report to NASA/MSFC, Huntsville, AL, pp. 46.
- Huffaker, R. M., T. R. Lawrence, R. J. Keeler, M. J. Post, J. T. Priestley, J. A. Korrell, 1980: Feasibility Study of Satellite-Borne Lidar Global Wind Monitoring Systems. NOAA Tech. Memo. ERLWPL-63, WPL, Boulder, CO, 124 pp.
- Huffaker, R. M. and F. F. Hall, Jr., 1982: Wind Comparison Measurements Between a Pulsed Doppler Lidar and Other Wind Sensors. Abstracts of the Eleventh International Laser Radar Conference, NASA Conf. Pub. 2228, Madison, WI.
- Kopp, F., R. L. Schwiesow, and C. Werner, 1984: Remote Measurements of Boundary Layer Wind Profiles Using a CW Doppler Lidar. J. Clim. and Appl. Meteor., Vol. 23, pp. 148-154.

SATELLITE DATA ANALYSIS

TITLE: Estimation of Precipitation from GOES IR imagery During FGGE — Application to diagnostic studies.

INVESTIGATOR: Franklin R. Robertson
Atmospheric Sciences Division, ED43
Marshall Space Flight Center, AL 35812
(205) 453-1944

RESEARCH OBJECTIVES:

1. Develop a method of estimating open-ocean rainfall and associated latent heat release via GOES IR satellite imagery.
2. Use remote precipitation estimates to investigate the role of diabatic forcing in the maintenance of the South Pacific Convergence Zone (SPCZ) during FGGE SOP-1.
3. Assess the significance of non-quasigeostrophic transports of energy in several cyclogenetic events preceding the development of a North Atlantic blocking episode during FGGE SOP-1.

SIGNIFICANT ACCOMPLISHMENTS IN FY-85:

1. Development of algorithm for estimating precipitation over oceanic regions. The bulk of the early FY-85 work was directed toward development of the single pixel indexing technique (SPI) which assigns a rain rate to GOES IR black-body temperatures, T_b , via a non-linear statistical relationship developed with raingauge measurements. The method was tested against radar-derived rainfall during GATE, raingauge measurements over coastal North Carolina and island stations in the South Pacific Ocean. Skill was found comparable to Arkin's method (1979 MWR) in convective situations. The results suggest that transferring a rain algorithm from one oceanic regime to another may not require substantial modification of coefficients or tunable parameters.
2. Production of rainfall estimates over the SPCZ during January 1979. 12h mean rainfall amounts have been produced for the region bounded by 10°N, 50°S, 120°W and 170°E during the period January 10-16, 1979. These estimates constitute a basic input to diagnostic calculations of diabatic heating over the SPCZ region.
3. Available Potential Energy (APE) and time-mean heat budgets. ECMWF level III-b data analyses have been used to compute several components of the APE balance in the South Pacific during the period January 10-18, 1979. The formulation of the budget equations follows Robertson (1985 Tellus) and initial results suggest an important role for conversion of APE to kinetic energy via diabatically forced ageostrophic motion.

CURRENT RESEARCH:

Recent work focuses on the APE and time-mean heat budgets which should be complete by April. An additional project underway is the modification of the SPI method to account for erroneous indications of

precipitation caused by cirrus shields preceding extratropical cyclones. Local time derivatives of IR T_b are being incorporated into the algorithm. Preliminary indications are that the correlation between observed and estimated rainfall near .80 may be obtained with this approach in mid-latitudes.

FY-85/86 PLANS:

1. Complete analysis of baroclinic and barotropic components of kinetic energy balance to complement APE work and to explain the origin of the motion field in the SPCZ.
2. Produce moisture analysis over the South Pacific and North Atlantic that is suitable for comparison with the heat and energy budgets.
3. Perform APE, KE and time-mean heat budget analyses on North Atlantic cyclone events and the accompanying blocking development.

FY-85 PUBLICATIONS:

Robertson, F. R., 1985: Reference pressure changes and available potential energy in isobaric coordinates. Tellus, Vol. 36, in press.

Robertson, F. R., 1985: Use of GOES IR imagery in estimating precipitation over oceanic regions. Submitted to J. Climate and Appl. Met., 17 pp.

Robertson, F. R., 1985: IR precipitation estimates in the South Pacific during FGGE SOP-1. Preprint, 16th Conference on Hurricanes and Tropical Meteorology, May 14-17, 1985, Houston, TX. American Meteorology Society, Boston, MA 02108, 2 pp.

TITLE: The Use of Satellite Data in Understanding and Predicting Convective and Large-Scale Dynamical Processes

INVESTIGATORS: John A. Dutton
Professor of Meteorology
(814) 865-1534

John H. E. Clark
Associate Professor of Meteorology
(814) 863-1581

Hampton N. Shirer
Assistant Professor of Meteorology
(814) 863-1992

Department of Meteorology
The Pennsylvania State University
University Park, PA 16802

ACCOMPLISHMENTS IN FY-84:

1. Observational Studies of the Index Oscillation. Mr. Robert Schlaak has completed his M.S. Thesis in which he has combined, in a unique way, conventional and NOAA-III and NOAA-IV Earth Radiation Budget (ERB) data to study the pronounced index oscillation of the 1974-75 winter. He has determined that the principal driving mechanism for the oscillation is barotropic wave-mean flow energy exchanges stimulated by the mean westerlies becoming periodically unstable. He has also determined that polar cap radiative processes are phased with the oscillation such as to reinforce it. Variations in mid and high latitude cloud cover resulting from intrusions of warm air into high latitude regions modulate the net radiative cooling in such a way as to reinforce strong mid-latitude westerlies because of thermal wind balance and thus intensify the oscillation.

2. Theoretical Studies of the Index Cycle and Blocking Phenomena. A two-layer truncated baroclinic spectral model was developed to study the long-term evolution of disturbances to a baroclinically unstable mean flow. Topography and crudely-parameterized radiative processes were accounted for. As a result of Mr. Schlaak's discovery of the underlying barotropic nature of the index oscillation as well as reviewers suggestions about the original manuscript, the model has been revised to allow for barotropic as well as baroclinic wave-mean flow interactions. The form-drag exerted by the topography on the barotropic part of the mean flow is larger than on the baroclinic part and thus we anticipate significant changes from the original calculations on the index oscillation when it is strongly modulated by topography.

3. Numerical Modeling of Index Cycle Variations. We believe that since the index oscillation accounts for a significant portion of atmospheric temporal variance, the long term predictability could be improved if reliable forecasts of the index oscillation were available. Two spectral models of the index oscillation, one barotropic and the other baroclinic, have been developed. The latter allows for moisture, radiation, land-sea

temperature contrasts, and energy exchanges with the underlying surface. They are currently being tested for conservation of energy and vorticity.

4. Theoretical and Observational Studies of Cloud Streets. Two manuscripts, Shirer (1984) and Shirer, et al. (1984), have been completed recently; these discuss results obtained from a three-dimensional truncated spectral model of moist convection in a shearing environment. In Shirer (1984), two possible cloud street modes arising from a combined Rayleigh/parallel instability were found to be possible — one having orientations for which the Fourier coefficient of the wind shear perpendicular to the roll was nearly zero and the other for which the Fourier coefficient of the shear parallel to the roll was nearly equal to that perpendicular to the roll. These two modes have different horizontal characteristic wavelengths that vary with wind speed at the top of the domain, which is usually taken to be the base of the inversion. In Shirer et al. (1984), analysis of aircraft data taken during 4 cloud street cases from KonTur revealed that in each case the mode for which both shear coefficients were nearly equal corresponded to the observed one.

Work was begun on a three-dimensional spectral model able to represent the convective modes developing as a result of the inflection point instability. In addition, satellite pictures and relevant upper air data have been archived for 30 cloud street days during the 1983-84 winter season; these will be used to assess the results obtained from the above Rayleigh/parallel and inflection point instability models.

PLANS FOR FY-85:

1. Observational and Theoretical Studies of the Index Oscillation. We plan to concentrate on the analysis of our six-coefficient baroclinic-barotropic spectral model of the index oscillation. In addition, the blocking phenomenon will be analyzed by seeking low and high index equilibria and examining their stability. Further observational studies are planned which will concentrate on establishing the conditions leading to the establishment of atmospheric blocking patterns and their subsequent maintenance. A mix of conventional and satellite data is anticipated just as in our study of the index oscillation.

2. Modeling of the Index Cycle. It is proposed that the two spectral models be used to produce forecasts from observed fields. The desired prediction quantities are the index values, and the points of regime changes. The index values are, of course, calculated directly from the forecast height field. The regime changes may be found by calculating the attractor associated with the forecast fields at certain points in the forecast cycle. If, for example, the associated attractor were calculated every 6 hours and changed after 36 hours, this would indicate a transition to another flow pattern. It is anticipated that several forecasts with slightly different initial conditions will be needed to establish the probability of a regime change. The form of the probability distribution for the change might take the form of a log-normal distribution. This sample stochastic approach also takes into account the possibility of no regime change — something the single forecast cannot handle.

The calculation of the attractor restricts the number of spectral components to about 60 (or less) for practical reasons of computer time and core. Thus, the initial fields must be restricted to just the larger observed features. Since current satellite observing systems are able to resolve these scales, analyses derived solely from satellite observations should serve as satisfactory initial data.

3. Cloud Streets. The new inflection point instability model will be developed sufficiently that orientation angles and horizontal wavelengths can be predicted for the rolls and these results compared to both the KonTur data and the locally archived data. Development of approximate formulas relating for each possible mode the orientation angles to components of the mean wind shear is one goal of the analysis.

Preliminary work is planned on generalizing the present three-dimensional Rayleigh/parallel instability model to one able to represent the transitions from rolls having one wavelength to ones having other, larger ones. Such cell broadening is observed in laboratory models of Rayleigh-Benard convection and in satellite pictures of cloud streets over the ocean, and is modeled well in a new simple spectral model of two-dimensional shallow convection given by Chang and Shirer (1984). The background wind field will likely play a crucial role in determining the details of this cell broadening, and will be an important factor in any usable boundary layer wind-measuring scheme.

PUBLICATIONS:

Shirer, H. N. and R. Wells, 1983: Mathematical Structure of the Singularities at the Transitions Between Steady States in Hydrodynamic Systems. Lecture Note in Physics, Vol. 185, 276 pp.

Feldstein, S. B., and J. H. E. Clark, 1984: The Hadley and Rossby Regimes on a Sphere. Monthly Weather Review. (To appear).

Chang, H-R and H.N. Shirer, 1984: Transitions in Shallow Convection: An Explanation for Cell Broadening. Journal of the Atmospheric Sciences. (To appear).

Shirer, H. N., 1984: On Cloud Street Development in Three Dimensions: Parallel and Rayleigh Instabilities. Contributions to Atmospheric Physics.

Shirer, H. N., B. Brummer and A. Grant, 1984: Cloud Streets During KonTur and the Parallel/Rayleigh Instability. Contributions to Atmospheric Physics.

Schlaak, R. A., 1984: An Observational Study of the Winter 1974/75 Index Oscillation with Conventional and Satellite ERB Data. Thesis and in preparation for submission to Monthly Weather Review.

TITLE: Variation Objective Analyses for Cyclone Studies

INVESTIGATORS: Gary L. Achtemeier
Illinois State Water Survey
Champaign, IL 61820

Stanley Q. Kidder
Illinois State Water Survey
Champaign, IL 61820

Harry T. Ochs
Illinois State Water Survey
Champaign, IL 61820

RESEARCH OBJECTIVES:

1. Develop an objective analysis technique that will maximize the information content of data available from diverse sources, with particular emphasis on the incorporation of observations from satellites with those from more traditional immersion techniques.
2. The diagnosis of the state of the synoptic scale atmosphere on a much finer scale over a much broader region than is presently possible to permit studies of the interactions and energy transfers between global, synoptic and regional scale atmospheric processes.

SIGNIFICANT ACCOMPLISHMENTS IN FY-85:

1. The variational objective analysis model (VASP Model 1) has been completed. This diagnostic model consists of the two horizontal momentum equations, the hydrostatic equation, and the integrated continuity equation for a dry hydrostatic atmosphere. The equations are non-dimensionalized, scaled, and are written in a non-linear sigma coordinate. Preliminary tests of the model with the SESMAE I data set are underway for 12 GMT 10 April 1979. At this stage the purpose of the analysis is not the diagnosis of atmospheric structures but rather the validation of the model. Model runs for rawinsonde data and with the precision modulus weights set to force most of the adjustment of the wind field to the mass field have produced 90 to 95 percent reductions in the imbalance of the initial data after only 4-cycles through the Euler-Lagrange equations. Realistic patterns and magnitudes of vertical velocity produced from the model differ substantially in some areas from the vertical velocities obtained from the O'Brien kinematic technique. Whether these differences represent an improvement will be determined in the near future.

2. Sensitivity tests for linear stability of the 11 Euler-Lagrange equations that make up the VASP Model 1 indicate that there will be a lower limit to the scales of motion that can be resolved by this method. Linear stability criteria are violated where there is large horizontal wind shear near the upper tropospheric jet.

3. We have developed a method to remove biases (compared to rawinsonde data) from satellite soundings. Time- and space-interpolated RAOB layer mean virtual temperature fields are compared with individual satellite soundings. Average differences for each of the sounding types (clear, partly cloudy, cloudy) are calculated for a two week period. Day and night average differences are calculated separately. These corrections, then, are applied to satellite soundings to remove average biases. This is particularly important because the different sounding types and the different time periods have quite different biases, which, if uncorrected, would require us to decrease the relative weights accorded to the TIROS-N temperature fields in the variational model.

4. The observations to be mutually adjusted must be initially gridded before they are introduced into the variational model. The initial gridding of the data is accomplished with the widely used Barnes successive corrections objective analysis method. A theoretical analysis of the filter response of this method has found that aside from reducing the amplitudes of long waves and shifting the phase of short waves near data boundaries, the method should produce reasonably good initial fields provided that the data are regularly spaced.

CURRENT RESEARCH:

1. VASP Model 1 is being rerun with different combinations of relative weights to determine how the variational model performs when the weighting favors adjustment of the mass field toward the wind field and when the temperatures receive the greatest relative weight.

2. The TIROS-N mean layer temperature data is being processed to remove biases. Then the TIROS-N temperatures will be introduced into the variational model and comparisons made between model runs with and without satellite data.

3. The VASP Model 1 is being extended by inclusion of the energy equation for dry, adiabatic motions. This will create a new variational model that contains all five of the primitive equations as constraints.

4. All of the model runs are being compared with a large number of meteorological parameters obtained through independent analyses by project staff or obtained through the meteorological literature.

5. We are developing a variational methodology to use satellite data to determine the relative weights to be accorded to vertical velocities calculated by the kinematic and adiabatic methods.

FUTURE PLANS:

1. Complete the formulation and evaluation of the 5-primitive equation diagnostic objective analysis model.

2. Develop a separate objective analysis method that combines data from various sources such as TIROS-N, VAS, GOES VIS and IR, surface observations, and rawinsonde data to grid fields of moisture.

3. Select a convective parameterization scheme, develop theory compatible with the variational equations, and modify the variational model for moist processes.

4. Develop theory to include radiances directly in the variational model through radiative transfer equation.

PUBLICATIONS SINCE JUNE 1984:

Achtemeir, G. L., Ochs, H. T., and S. Q. Kidder: A diagnostic numerical model for the application of satellite data for the study of global weather systems. Reprints, Conference on Satellite Meteorology/Remote Sensing and Applications 25-29 June 1984, p. 260.

Achtemeir, G. L., 1985: On the impact of data boundaries upon the objective analysis of limited-area data sets. Submitted to Monthly Weather Review.

Achtemeir, G. L., 1985: On the notion of varying influence radii for successive corrections objective analysis. To be submitted to J. Climate and Appl. Meteor.

TITLE: Utilization of Satellite Cloud Information to Diagnose the Energy State and Transformations in Extratropical Cyclones

INVESTIGATOR: Phillip J. Smith
Department of Geosciences
Purdue University
West Lafayette, IN 47907
(317) 494-3286

SIGNIFICANT ACCOMPLISHMENTS IN FY-85:

An important component of our research has been a continuing investigation of the impact of latent release on extratropical cyclone development. Previous efforts to accomplish this task have focused on the energy balance and the vertical motion field of an intense winter extratropical cyclone over the United States. During this fiscal year we turned our attention to a more fundamental diagnostic variable, the height tendency. Central to this effort is the use of a modified form of the quasi-geostrophic height tendency equation, in which geostrophic wind components have been replaced by observed winds and a latent heat release term has been added. This methodology was adopted to produce a simple diagnostic model which retains the essential mechanisms of quasi-geostrophic theory but more faithfully describes observed wave development when the Rossby Number approaches and exceeds 0.5.

Results to date indicate that the new model yields height tendencies that are superior to those obtained from the quasi-geostrophic formulation and are sufficiently close to the observed tendencies to be a useful tool for diagnosing the principle large-scale forcing mechanisms in the 700-300 mb layer. Of the three forcing terms included in the new model (vorticity advection, differential thermal advection, and differential latent heat release), vorticity advection is in general dominant for this case. The most persistent challenge to this dominance is made by the thermal advection. On the whole, latent heat release plays a secondary role. However, it can be very significant in limited regions experiencing intense heating, where it preceded by 12 hours sharp increases found in height falls forced by vorticity advection. Finally, during the rapid intensification observed for this cyclone (sea level pressure decrease of 17 mb over a 24 hour period), all three processes complement each other in forcing height falls.

FOCUS OF CURRENT RESEARCH ACTIVITIES:

1. Analysis and interpretation of the height tendency calculations is nearing completion.

2. We are attempting to replicate and extend the latent heat modification scheme described in the M.S. thesis of S.-J. Lin. Calculation of latent heat release using conventional data for the SESAME I period is now in progress using analyzed fields provided by MSFC. These will be compared with estimates derived from a model developed by MSFC scientist, Dr. Franklin Robertson, and, in addition, will be modified using available satellite data.

PLANS FOR FY-86:

We expect to complete our study of the SESAME I case and focus our attention on a new investigation. This latter effort is concerned with the significance of non-quasigeostrophic processes in synoptic/planetary-scale interactions, with particular emphasis on the development of a blocking episode over the North Atlantic Ocean as revealed in the FGGE data set during 7-27 January 1979. We have acquired a complete set of SOP I FGGE data from the Goddard Laboratory for Atmospheric Science.

PUBLICATIONS SINCE JUNE 1984:

1. Refereed publication

Smith, P. J., P. M. Dare, and S.-J. Lin, 1984: The impact of latent heat release on synoptic-scale vertical motions and the development of an extratropical cyclone system. *Mon. Wea. Rev.*, Vol. 112, pp. 1421-2430.

2. Submitted papers

Lin, S.-J., and P. J. Smith, 1985: Utilization of satellite cloud cover to improve the estimation of latent heat release in a developing extratropical cyclone. Submitted to *Mon. Wea. Rev.*

Smith, P. J., and P. M. Dare, 1985: The kinetic and available potential energy budget of a winter extratropical cyclone system. Submitted to *Tellus*.

3. Presented paper

Smith, P. J., and C.-H. Tsou, 1985: Adiabatic and diabatic forcing of the development of a winter extratropical cyclone. Accepted for presentation at the 7th Conference on Numerical Weather Prediction, June 17-20, 1985, Montreal.

TITLE: Dynamics and Energetics of the South Pacific Convergence Zone
During FGGE SOP-1

INVESTIGATOR: Dayton G. Vincent
Department of Geosciences
Purdue University
West Lafayette, IN 47907
(317) 494-3290

SIGNIFICANT ACCOMPLISHMENTS TO DATE:

At this writing the contract is near the midpoint of its 3-year duration. As stated in last year's annual review report, the contract has two major research objectives: (1) to diagnose the physical processes responsible for the maintenance of the South Pacific Convergence Zone (SPCZ) and (2) to examine the role of the SPCZ in the large-scale circulation patterns of the Southern Hemisphere. To accomplish these objectives we have used several data sources which include: a modified set of Level III-b upper air analyses, originally produced by ECMWF (Vincent, 1982); subjectively-analyzed surface analyses for the South Pacific, based on island station reports (Vincent, 1985); outgoing longwave radiation values supplied to us by NOAA/NESDIS; and equivalent black body temperatures and precipitation rates derived by Robertson (see elsewhere in this report).

In the past year we have found that wave number four plays an important role in the Southern Hemisphere tropics during the 15-day period when the SPCZ was a dominant feature, particularly with regard to the baroclinic conversion of potential to kinetic energy (Huang and Vincent, 1985). The convectively-active SPCZ area was found to make a significant contribution to this conversion process; thus, it appears that baroclinic effects and latent heating are important in maintaining the SPCZ. Recently, our efforts have concentrated on two research tasks, an examination of cyclone activity within the SPCZ (Kann, 1985; Vincent, 1985; Vincent and Kann, 1985) and a study of the heat and moisture budgets in the South Pacific (Miller, et al., 1985). We have found that cyclonic disturbances occurred with regularity in the Zone from 10-17 January. Three cyclones, which developed and moved along the SPCZ, are being investigated. One cyclone remained tropical, while the other two propagated into middle latitudes and took on frontal characteristics. Satellite estimates have shown that areas of maximum precipitation are located in the vicinity of each cyclone. Preliminary results of our budget studies show good agreement with patterns of satellite-derived precipitation.

A number of events have complemented our research accomplishments. In June 1984, Dr. Vincent presented a paper at the Tenth Conference on Weather Forecasting and Analysis at Clearwater Beach, Florida (Huang and Vincent, 1984). In July 1984, Dr. Robertson visited Purdue and participated in Ms. Kann's Ph.D. preliminary examination. Also, in July Dr. Huo-Jin Huang successfully defended his Ph.D. dissertation (Huang, 1984) and in August accepted a position of assistant professor in the atmospheric science program at the University of North Carolina, Asheville. In January 1985, Dr. Vincent went to MSFC/Huntsville for a few days to discuss research with Dr. Robertson. In March 1985, Dr. Vincent gave a paper

in a poster session on "Atmospheric Wave Activity in the Southern Hemisphere During FGGE, 10-27 January 1979," at the Fifth Conference on Atmospheric and Oceanic Waves and Stability, held in New Orleans, Louisiana. In March 1985, Dr. Vincent visited GLA/NASA and NASA Headquarters to present a seminar and discuss current and future research plans.

FOCUS ON CURRENT RESEARCH:

A cumulus, parameterization scheme, developed by Dr. Robertson, at MSFC/NASA, is being applied to the SPCZ area to obtain vertical profiles of latent heating. This will allow us to estimate the significance of latent heat, compared to quasi-geostrophic contributions, in the vertical motion field and, hence, in the baroclinic energy conversion process. Also, we are attempting to finalize our heat and moisture budget studies in the SPCZ area. When completed, this work will produce a M.S. Thesis by Miller, which is projected to occur in late summer of this year. Recently, we obtained a global set of analyses for SOP-1, compliments of GLA/NASA. We are in the process of preparing this data set so that we can extend our period of investigation and examine the circulations in the Southern Hemisphere beyond 27 January 1979.

PLANS FOR FY-86:

In the coming year we plan to complete the aforementioned heat and moisture budget investigation begun by Mr. Miller and the SPCZ cyclone case study, begun by Ms. Kann. Also, we plan to compare the energy budget calculations conducted by Drs. Huang and Vincent, based on ECMWF Level III-b analyses, to those derived from GLA analyses. In addition, we plan to convert the recently-acquired NCAR Community Climate Model (CCM) for use on Purdue's CYBER-205 computer. This project is one of the major tasks scheduled for Dr. Huang who will be spending the summer at Purdue as a post-doctoral research associate.

RECOMMENDATIONS FOR NEW RESEARCH:

Future work beyond the next year most likely will include some experiments, using both the GLA GCM and the NCAR CCM, designed to better understand the role of the SPCZ in the planetary-scale circulation of the Southern Hemisphere.

PUBLICATIONS SINCE JUNE 1984:

Huang, H.-J., 1984: The South Pacific Convergence Zone and Energy Balance of the Southern Hemisphere. Ph.D. Thesis, Department of Geosciences, Purdue University, West Lafayette, Indiana, 47907, 130 pp.

Huang, H.-J. and D. G. Vincent, 1984: Potential to Kinetic Energy Conversion in Wave Number Domain for the Southern Hemisphere. Tenth Conference on Weather Forecasting and Analysis, Clearwater Beach, Florida, American Meteorological Society, Boston, MA, 6 pp.

Huang, H.-J. and D. G. Vincent, 1985: Significance of the SPCZ in Energy Conversions of the Southern Hemisphere during FGGE, 10-27 January 1979. (Accepted by Mon. Wea. Rev.)

Kann, D. M., 1985: Case Study of a Tropical Cyclone in the South Pacific during FGGE. Preprint, Sixteenth Conference on Hurricanes and Tropical Meteorology, May 14-17, 1985, Houston, TX, American Meteorological Society, Boston, MA, 02108, 2 pp.

Miller, B. L., D. G. Vincent, and F. R. Robertson, 1985: Precipitation Estimated for the Tropical South Pacific during FGGE, 10-18 January 1979. Preprint, Sixteenth Conference on Hurricanes and Tropical Meteorology, May 14-17, 1985, Houston, TX, American Meteorological Society, Boston, MA, 02108, 2 pp.

Vincent, D. G., 1985: Cyclone Development in the South Pacific Convergence Zone. Preprint, Seventh Conference on Numerical Weather Prediction, June 17-20, 1985, Montreal, Canada, American Meteorological Society, Boston, MA, 02108, 6 pp.

TITLE: Application of Satellite Data to Tropic/Subtropic Moisture Coupling

INVESTIGATORS: James P. McGuirk
Aylmer H. Thompson
Department of Meteorology
Texas A&M University
College Station, TX 77843-3146
(409) 845-4431 or 845-3919

RESEARCH OBJECTIVES:

Our objective is to develop analysis tools for use of satellite data to interpret synoptic-scale systems in data-void regions. Our interim goals are to: (1) quantify the synoptic information content of satellite data; and (b) utilize these data in the diagnosis of "moisture bursts" in the eastern tropical Pacific Ocean during FGGE.

SIGNIFICANT ACCOMPLISHMENTS IN FY-85:

1. Description of Satellite Channel Data

a) We have developed and implemented a statistical procedure for using TIROS N microwave data to infer infrared channel data for overcast conditions; we use the same procedure for deducing full TIROS N channel radiance profiles from NOAA 5 VTPR channel data over regions where the TIROS N data are missing.

b) Satellite-sensed temperature and moisture signals vary on different horizontal scales; these two signals vary differently, but consistently, within moisture bursts.

c) We have completed an empirical orthogonal function analysis of twice-daily channel radiance fields over the tropical eastern Pacific. The vertically oriented eigenfunctions are interpreted in terms of typical meteorological events. The horizontal distribution of the eigenfunction amplitudes relate these meteorological signals to moisture bursts.

2. Synoptic Evaluation of Winter Moisture Bursts

a) A pair of moisture burst climatologies is complete: one of four years using infrared imagery (including the highly anomalous 1982-83 cold season); the other implementing 850 to 200 mb wind analyses in conjunction with GOES imagery.

b) We have compared a number of different evaluations of the synoptic evolution of moisture fields (enhanced infrared imagery, moisture channel data, FGGE humidity analysis, and in situ station and sounding observations). All have limitations; all can be utilized together; all together are still less than adequate in the tropical Pacific.

3. Related Projects

a) A wind study has revealed synoptic scale analysis errors in the European Center analysis, with respect to cloud drift wind estimates. Coherent vertical wind shears appear related to moisture burst structure.

b) A synthesis of wind analyses, published wind climatologies and burst climatologies indicates two different modes of ITCZ behavior: a weak synoptic-scale mode characteristic of the eastern Pacific cold season; and a strong convective-scale mode characteristic of western oceans, the summer Pacific Ocean, and El Niño periods.

FOCUS OF CURRENT RESEARCH:

Current efforts involve several subtasks. These may be listed as follows:

1. Completion, as far as we will pursue it, of the moisture burst climatology. Emphasis on November-April events, but some May-June events are included.
2. Studies of interpretation of individual channel radiance fields.
3. Definition of the synoptic moisture fields in the eastern tropical Pacific Ocean.
4. Case studies of two cold-season (January 1979) and one warm-season (May 1979) moisture bursts.
5. Wind analysis and comparison with actual wind observations.
6. A pilot study of divergence estimators for the tropics.

PLANS FOR FY-86 AND NEW RESEARCH:

Most, if not all, of the tasks listed above should be completed by the end of August 1985. The graduate students/research assistants involved should have completed their degree work (we anticipate four theses and one dissertation) and gone on to other things. Because of this "changing of the guard" and an anticipation of at least four new graduate students, we blend "Plans for FY-86" and "New Research." The goals may be listed thusly:

1. We intend to complete the current research thrusts, including appropriate publications.
2. Using a study by Julian (1984: Mon. Wea. Rev., Vol. 112, pp. 1752-1767), we will test the capability of the use of individual channel data to estimate tropical divergence, either alone or in conjunction with wind analyses.
3. We will attempt to complete our efforts to merge cloud imagery, channel radiance data and European Center analyses to determine to what extent each can augment the others in constructing a model of moisture bursts.

4. We will initiate four new investigations:

a) Based on the detailed variations shown in nearby soundings, we will use satellite channel data to infer the horizontal variations of detailed atmospheric structure.

b) We will initiate new case studies comparing TIROS N and GOES VAS channel data over the Pacific Ocean.

c) We will use simple existing wave models to interpret satellite and other data in the moisture burst region.

d) We will utilize current techniques to perform a moisture budget analysis of the moisture bursts which we are examining in detail.

PUBLICATIONS/PRESENTATIONS, JUNE 1984-MAY 1985:

McGuirk, J. P., L. L. Anderson, Jr., and A. H. Thompson, 1985: Satellite-Derived Synoptic Climatology in Data-Sparse Regions. *Advances in Space Research*, Vol. 4, Pergamon Press. In press.

McGuirk, J. P., A. H. Thompson and N. R. Smith, 1984: Observing the Eastern Pacific Hadley Circulation. *Proceedings of the Ninth Annual Climate Diagnostics Workshop*. Corvallis, OR, October 22-26, 1984, pp. 429-436.

McGuirk, J. P. and A. H. Thompson, 1985: Two Modes in the Pacific Hadley Cell. Preprint Vol., 16th Conference on Hurricanes and Tropical Meteorology, Amer. Meteor. Soc., Houston, TX, 14-17 May 1985. In press.

Smith, N. R., J. P. McGuirk and A. H. Thompson, 1985: The Synoptic Structure of Tropical Pacific Moisture Bursts. Preprint Vol., 16th Conference on Hurricanes and Tropical Meteorology, Amer. Meteor. Soc., Houston, TX, 14-17 May, 1985. In press.

Thompson, A. H., M. P. McGuirk, L. L. Anderson, Jr., and N. R. Smith, 1984: Analysis of Tropical Synoptic Disturbances Using Satellite-Derived Soundings and Radiance Data from Selected Channels. Preprint Vol., Conference on Satellite/Remote Sensing and Applications, Amer. Meteor. Soc., Clearwater Beach, FL, 25-29 June, 1985, pp. 137-142.

Thompson, A. H., J. P. McGuirk, and L. L. Anderson, Jr., 1985: Comparisons Between Tropical Synoptic Moisture Fields as Determined from Analysis and from Observations. Preprint Vol., 16th Conference on Hurricanes and Tropical Meteorology, Amer. Meteor. Soc., Houston, TX, 14-17 May, 1985. In press.

TITLE: Observational and Theoretical Studies of the Evolving Structure of Baroclinic Waves: Attractor Dynamics of Global Weather Systems.

INVESTIGATORS: Barry Saltzman
Anthony R. Hansen
Richard N. Nagle
Department of Geology and Geophysics
Yale University
P.O. Box 6666
New Haven, CT 06511
(203) 436-0494

Chung-Muh Tang
Universities Space Research Association
The American City Building, Suite 311
Columbia, MD 21044
(215) 449-4853

SIGNIFICANT ACCOMPLISHMENTS IN FY-85:

1. Low-order modeling of global weather dynamics. Significant progress was made in developing a six-component dry model of mid-latitude baroclinic wave evolution, and a ten-component moist model. These models include representations of airflow over mountains and non-adiabatic processes. As a first step, the properties of a reduced, three component, baroclinic system are studied. The classical baroclinic stability criteria emerge as the properties of one of the three equilibria admitted, with the remaining two equilibria forming the attractor region for the observed weather activity. (Saltzman and Tang)

2. Passive tracer evolution in a baroclinic wave. The previous model described in reference 3 in which only constituents trapped within low atmospheric levels are considered, has been extended to include the possibility for fluxes into the upper levels of the atmosphere. The reported results for the lower levels achieved previously are shown to be qualitatively similar to those obtained by these new calculations in which the vertical flux constraint is removed. (Tang)

3. Satellite signatures of atmospheric blocking. An extensive study of an 8-year record of global outgoing longwave radiation for the Northern Hemisphere reveals that blocking events exhibit only a weak signature of blocking highs, as measured by relatively low values of the ratio of the standard deviation to the mean value of the observed long wave outgoing radiation. Though present in many cases, the signature is not a strongly distinctive feature of the blocking episodes. (Nagle and Saltzman)

FOCUS OF CURRENT RESEARCH AND PLANS FOR FY-86:

We are now engaged in a detailed step-by-step analysis of the six and ten-component models referred to above. Our overall objective is to use these models in conjunction with the continuous records provided by

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satellite-derived measurements of atmospheric and surficial variability, to deepen our understanding of the observed time variability of the global weather system. Special emphasis will be given to the possibility for transition between more ordered states perhaps identifiable with "blocking" and more chaotic states perhaps identifiable with "geostrophic turbulence."

PUBLICATIONS PREPARED SINCE JUNE 1984:

1. Brown, Philip S., A. R. Hansen, and J. P. Pandolfo, 1985: Average Characteristics of Blocking and Nonblocking Events. J. Atmos. Sci., (in press).
2. Nagle, Richard L., 1984: Climatological Aspects of the Outgoing Long-wave Radiation Field of the Northern Hemisphere Mid-Latitude. Master of Science Thesis, Yale University, pp. 59.
3. Saltzman B. and C.-M. Tang, 1985: The Effect of Finite-Amplitude Baroclinic Waves on Passive, Low Level, Atmospheric Constituents, with Applications to Comma Cloud Evolution. Tellus, Vol. 37A, pp. 41-55.

ATMOSPHERIC ELECTRICITY

88521-08W

N86-15782

TITLE: Deep Convection in Mesoscale Convective Systems

INVESTIGATOR: Steven J. Goodman
USRA Visiting Scientist Program
NASA/MSFC ED43
(205) 453-1325

SIGNIFICANT ACCOMPLISHMENTS TO DATE IN FY-85:

A study has been undertaken to examine the evolution of radar echoes and lightning attending the convective storms in mesoscale convective systems and the relationships between the spatial and temporal evolution of deep convection and the storm environment, precipitation, severe weather, and lightning. The total number of ground discharges ranges from 10,000 to 30,000 over the life cycle of the MCS with peak sustained rates (for up to 10 consecutive hours) in excess of 2000 per hour. The peak lightning activity occurs from 5 to 20 hours after the first storms and anywhere from 7 hours prior to 7 hours after the time of the maximum areal extent of the MCS for very similar synoptic environments. Thus, it appears that mesoscale and sub-synoptic scale mechanisms are responsible for these large temporal variations in lightning activity. In addition, we have found that the lightning rates in MCS's are not related to either the size or the duration of the MCS. Preliminary results suggest that the MCS's with embedded squall lines produce the greatest flash rates.

FOCUS OF CURRENT RESEARCH ACTIVITIES:

The examination of lightning activity and its relationship to the distribution, evolution and structure of convective storms and their environment will continue. Development of a stochastic model for lightning diagnosis and forecasting has begun. Volume scan radar data collected during Hurricane Alicia is being compared with the sferics data collected by the phase linear interferometer.

PLANS FOR FY-86:

Continue with existing research and specifically (1) identify an optimal technique for lightning ground strike clustering for storm identification; (2) evaluate GOES VIS/IR data for identifying storms likely to produce lightning; (3) implement the NEXRAD codes on the MSFC PE.3250 to study convective and stratiform precipitation in MCS's; (4) investigate the utility of lightning and volume scan radar data for estimation of diabatic heating rates.

PUBLICATIONS SINCE JUNE 1984:

Goodman, S. J. and D. R. MacGorman, 1984: A Composite Picture of Lightning Activity in Mesoscale Convective Complex. EOS, Vol. 65, p. 849.

Rust, W. D., W. L. Taylor, D. R. MacGorman, E. Brandes, V. Mazur, R. Arnold, T. Marshall, H. Christian and S. J. Goodman, 1985: Lightning and Related Phenomena in Isolated Thunderstorms and Squall Lines. Accepted by J. of Aircraft.

TITLE: Severe Storm Electricity

INVESTIGATORS: Dr. W. David Rust and Dr. Donald R. MacGorman
NOAA/National Severe Storms Lab
Norman, OK 73069
(405) 360-3620, FTS 736-4916

SIGNIFICANT ACCOMPLISHMENTS IN FY-85:

During FY-85, we have conducted a field program and analyzed data. The field program incorporated coordinated measurements made with a NASA U2. Additional results from this program are also reported by others elsewhere in this Review. Results include the following:

1) Ground truth measurements of lightning for comparison with those obtained by the U2. These measurements have included electric field changes, flash type identification, optical wave forms, and ground strike location. Sensors at NSSL and on the UM/NSSL mobile laboratory were used.

2) Analysis of dual-Doppler radar and dual-VHF lightning mapping data from a supercell storm. Initial indications show differences between this supercell and a multicell storm analyzed previously, including no distinct and separate category of high intracloud lightning in the supercell. There is a preference for lightning to be found in regions of moderate horizontal shear of vertical velocity (5 to 11 m/s/km). There are other aspects of this analyses and comparison too lengthy to include here.

3) Analysis of synoptic conditions during three simultaneous storm systems on 13 May 1983 when unusually large numbers of positive cloud-to-ground (+CG) flashes occurred. While most storms that occurred on this day produced severe weather, a well-defined mesocyclone and very intense reflectivity were apparent for only one system. A second, squall line system produced hail and funnels, but no reported tornadoes. The third system, an isolated storm, produced the largest tornadoes on this day, but had reflectivity of <55 dBZ and no easily identifiable mesocyclone on the Doppler display. Almost all CG lightning in the first group lowered negative charge; the flash polarity was about equally divided in the squall line; and nearly synoptic scale variables shows differences in the vertical shear of the horizontal wind in the layer between 850-350 mb that appear consistent with the locations of the most numerous +CG flashes.

4) Analysis of extremely low frequency (ELF) wave forms. ELF data have proved essential for documentation of CG flash occurrence and identification of its polarity, are providing "ground truth" for assessment of our ground strike locating system, and will be very useful for combination with data from the proposed satellite lightning mapper.

5) An assessment of our CG strike location system (manufactured by LLP) using a combination of mobile laboratory and fixed-base TV video data was begun in FY-84 and completed this year. We found a detection efficiency of about 70 percent for CG flashes both within the interior of the network and out to a range of about 300 km from the network center. Site errors

were also established, and their inclusion provides more accurate CG locations for comparison with the U2 and other storm research data.

6) Photographic verification of continuing current in +CG flashes.

7) Initial work on expansion of NSSL's lightning ground strike locating system for mesoscale studies. Coverage of the expanded, 7-site network will include Oklahoma, north Texas, Kansas, southern Nebraska, and portions of other contiguous states. (Funding comes from other sources, but the capabilities will be useful in anticipated future research under this program.)

8) Setup and testing of our VHF lightning mapping system to record data from the entire hemisphere continuously. This upgrade will enhance our ability to locate and compare lightning with other storm parameters.

FOCUS OF CURRENT RESEARCH ACTIVITIES:

At present we are involved in data acquisition, including use of the UM/NSSL mobile laboratory in our storm intercept program to acquire intracloud lightning data. One goal is to increase our efforts to test the indication that intracloud lightning may be tied tightly to the strength of mesocyclones and to ascertain whether there are unusually high intracloud lightning rates in storms producing significant hailfall. Specified as part of our current work statement and now well underway is an analysis of a large data set of +CG flashes to assess how well our ground strike locating system detects these flashes, a necessary step in our continued search for clarifying the apparent relation between positive ground flashes and certain weather systems, including storms with mesocyclones and mature squall lines.

PLANS FOR FY-86:

We will continue analyses already in progress and begin additional storm studies within the areas listed above. We will continue cooperative analyses with scientists at NASA/MSFC and others as outlined herein and in other reports in this Review. Participation with the U2 storm overflight program as part of COHMEX is being discussed. Relationships between microphysical and electrical processes will be investigated using dual-polarized and vertically pointing Doppler radar in conjunction with electrical measurements.

RECOMMENDATION FOR NEW RESEARCH:

We see increasing emphasis on the study of lightning and storms, especially in mesoscale systems such as are presently the focus during PRESTORM, and on intracloud lightning as outlined above. We recommend an immediate commitment to put into service the satellite-borne lightning mapper system. Without such a mapper, we are highly restricted in our ability to utilize lightning in mesoscale research because of the large areal extents that must be mapped for both intracloud and CG lightning. Data from other satellite and radar meteorology techniques will need to be combined readily with such satellite lightning data; such capabilities exist at MSFC and may be on line at NSSL in the near future.

PUBLICATIONS SINCE JUNE 1984:

Taylor, W. L., E. A. Brandes, W. D. Rust, and D. R. MacGorman: Lightning Activity and Severe Storm Structure. *Geophys. Res. Ltr.*, Vol. 11, pp. 545-548, 1984.

Rust, W. D., W. L. Taylor, D. R. MacGorman, E. Brandes, V. Mazur, R. Arnold, T. Marshall, H. Christian, and S. J. Goodman: Lightning and Related Phenomena in Isolated Thunderstorms and Squall Line Systems. *J. of Aircraft*, to be published in May 1985.

Mazur, V., D. S. Zrnica, and W. D. Rust: Lightning Channel Properties Determined with a Vertically Pointing Doppler Radar. *J. Geophys. Res.*, accepted for publication in 1985.

Rust, W. D., D. R. MacGorman, and W. L. Taylor: Photographic Verification of Continuing Current in Positive Cloud-to-Ground Flashes. *J. Geophys. Res.*, accepted for publication in 1985.

MacGorman, D. R., M. W. Maier, and W. D. Rust: Lightning Strike Density for the Contiguous United States from Thunderstorm Duration Records. NUREG/CR-3759, report to U.S. Nuclear Regulatory Commission, May 1984.

Marshall, T. C., W. D. Rust, and W. P. Winn: Screening Layers at the Surface of Thunderstorm Anvils. Preprints, pp. 246-247, 7th Intl. Conf. on Atmos. Elec., Albany, New York, June 4-8, 1984.

MacGorman, D. R., W. L. Taylor, W. D. Rust, and R. T. Arnold: Some Characteristics of Lightning in Severe Storms on the Great Plains of the United States. Preprints, pp. 299-304, 7th Intl. Conf. on Atmos. Elec., Albany, New York, June 4-8, 1984.

Goodman, S. J., H. J. Christian, W. D. Rust, D. R. MacGorman, and R. T. Arnold: Simultaneous Observations of Cloud-to-Ground Lightning Above and Below Cloud Tops. Preprints, pp. 456-462, 7th Intl. Conf. on Atmos. Elec., Albany, New York, June 4-8, 1984.

Mazur, V., D. S. Zrnica, and W. D. Rust: Lightning and Precipitation Velocity Spectra Determined with a Vertically Looking Radar. Preprints, pp. 91-96, 7th Intl. Conf. on Atmos. Elec., Albany, New York, June 4-8, 1984.

Mazur, V., J. Gerlach, W. D. Rust, and R. Henson: Evaluation of Lightning Distribution Within a Squall Line Determined with S- and VHF-band Radars. Abstract, *Eos*, Vol. 65, p. 841, 1984.

Rust, W. D. and Mazur, V.: Relationships Between Lightning Radar Echoes and VHF Impulse Sources. Abstract, *Eos*, Vol. 65, p. 841, 1984.

Mach, D. M., D. R. MacGorman, W. D. Rust, and R. T. Arnold: Site Errors in a Lightning Strike Locating System in Oklahoma. Abstract, *Eos*, Vol. 65, p. 842, 1984.

Goodman, S. J., and D. R. MacGorman: A Composite Picture of Lightning Activity in Mesoscale Convective Complexes. Abstract, *Eos*, Vol. 65, p. 849, 1984.

TITLE: Storm Severity Detection (RF)

INVESTIGATORS: Dr. R. L. Johnson
Electromagnetics Division
Southwest Research Institute
San Antonio, TX 78284
(512) 684-5111, Ext. 2765

S. J. Goodman
Atmospheric Science Division
NASA/Marshall Space Flight Center, AL 35812
(205) 453-1325

SIGNIFICANT ACCOMPLISHMENTS TO DATE IN FY-85:

Atmospheric electrical emissions occurring in association with Hurricane Alicia were observed by two crossed baseline phase linear interferometers. The sensors were located in San Antonio, Texas, and at Marshall Space Flight Center, Huntsville, Alabama. An analysis of the data has indicated that the direction finding (DF) performance of the San Antonio site was extremely good while the DF performance at the MSFC site evidenced erratic behavior. A check of the data acquisition hardware revealed an intermittent problem in one of the radio receiver channels. Since the system had experienced several lightning strikes during the early spring of 1984, it was necessary to ship the entire rack of equipment back to SwRI for refurbishment.

FOCUS OF CURRENT RESEARCH ACTIVITIES:

Analysis of the DF data from the interferometer site at San Antonio is being done. A limited subset of the MSFC data acquired during Hurricane Alicia has been found to be valid. These were data which satisfied the phase linearity criteria. Approximately 2,000 location estimates have been produced on the valid data. The results of the DF analysis and the location data are being correlated with the McIDAS data base at Marshall Space Flight Center, and with the radar summary data provided by the Hurricane Research Division using the NWS radar facility at Galveston, Texas.

PLANS FOR FY-86:

Refurbishment of the MSFC phase linear interferometer is being completed and the system is scheduled for redeployment during June 1985. Atmospheric electrical activity associated with hurricanes will be monitored by the direction finders located in San Antonio and Huntsville during the tropical storm season of 1985.

Analysis of the Hurricane Alicia data will be completed. In particular, the DF data from the San Antonio site will be reviewed for particular centers of electrical activity embedded in the tropical storm.

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RECOMMENDATIONS FOR NEW RESEARCH:

Provide capability of acquiring location data at higher frequencies so that diurnal electrification processes may be investigated, exploiting atmospheric radio emissions to 2000 km range.

Establish a data communication network between SwRI and MSFC to provide real time lightning location data to the McIDAS data base supporting satellite-borne sensors and ground based severe storm detection.

TITLE: Studies of Lightning Data in Conjunction with Geostationary Satellite Data

INVESTIGATORS: Brian Auvine (608-263-2152)
David Martin (608-262-4363)
Space Science & Engineering Center
University of Wisconsin
Madison, WI 53706

ACCOMPLISHMENTS IN FY-85:

Since January, work has been proceeding on the first phase of this project: the creation of an extensive real-time lightning data base accessible via the SSEC McIDAS system. Contacts have been made with many of the major lightning networks including MSFC, NSSL, SUNY's East Coast Network, the LPATS networks (via the National Severe Storms Forecast Center and R*Scan Corporation), and the Bureau of Land Management to arrange for access to their data during the period of May through September 1985. With the exception of the BLM which is in the process of redefining its user's policy, all of these networks have generously consented to such access on a trial basis. The purpose of this endeavor is two-fold: to enhance the availability and ease of access to lightning data among the various networks, governmental and research agencies; and to test the feasibility and desirability of such efforts in succeeding years.

FOCUS OF CURRENT RESEARCH ACTIVITIES:

The final steps in the creation of the necessary communications links, hardware, and software are in the process of being completed. Operations ground rules for access among the various users have been discussed and are being refined. While the research planned for the last year of the project will rely for the most part on archived, quality-controlled data from the various networks, the real-time data will provide a valuable "first-look" at potentially interesting case studies. For this purpose, tools are being developed on McIDAS for display and analysis of the data as they become available. In conjunction with concurrent GOES real-time imagery, strike locations can be plotted, gridded and contoured, or displayed in various statistical formats including frequency distributions, histograms, and scatter plots. The user may also perform these functions in relation to arbitrarily defined areas on the satellite image. By mid-May these preparations for the access and analysis of real-time lightning data are expected to be complete.

PLANS FOR FY-86:

During the real-time phase, we will have ample opportunity to compare the occurrence of lightning relative to features observed in both the visible and infrared satellite imagery. These preliminary observations will be directed toward measurement of anvil expansion relative to stroke frequency and the location of anvil features such as cold spots and overshooting tops in relation to stroke location. From a climatological point of view, we would also like to correlate over time the frequency of stroke occurrence relative to fractional cloud coverage as defined by various infrared thresholds. To take

advantage of the wide geographical range of the data, the results from the investigations above will be categorized and compared to a number of geographical/meteorological conditions (e.g., air mass versus frontal thunderstorms). Real-time results will be corrected and refined using the reprocessed quality-controlled data. If time and resources permit, radar data will be obtained to allow precipitation location and intensity to be included as additional variables in the analysis.

RECOMMENDATIONS FOR NEW RESEARCH:

Initial indications from this contract indicate that an extensive lightning data base is valuable to the research and operations community in a variety of ways. Both the NOAA managed VAS operations here at Wisconsin and the National Severe Storms Forecast Center in Kansas City have plans to use this data base as part of their forecast verifications of convection. Such applications would be encouraged and broadened by continued access to a nationwide lightning data base. Within the research community, a more comprehensive view of lightning phenomenon among the various network users seems at this point to be a likely outgrowth of this pooling of resources and data. Further steps in this direction would be warranted. As regards the particular interest this contract has in the study of lightning data in conjunction with satellite data, there is ample room for expansion of this effort. For instance, as yet neither satellite microwave nor water vapor imagery have been explored for their contribution toward the understanding of lightning phenomenon. The upcoming SPACE-MIST programs should offer some excellent opportunities to exploit these avenues of research.

TITLE: Lightning Mapper and the Future

INVESTIGATOR: Hugh J. Christian
Atmospheric Sciences Division
NASA/Marshall Space Flight Center, AL 35812
(205) 453-2463

SIGNIFICANT ACCOMPLISHMENTS IN FY-85:

A trade-off analysis was completed that reveals how the lightning mapper detection efficiency will change as a function of interference filter bandwidth, pixel field of view, and telescope aperture. It is shown that the critical parameter on which we have minimum flexibility is filter bandwidth. The problem is that too narrow a filter bandwidth is incompatible with wide areal coverage. The trade-off analysis demonstrates that an 80 percent lightning detection efficiency will technically be relatively straightforward, while a 90 percent detection efficiency will apparently be difficult to achieve. Three focal plane designs are currently under consideration. One would use a single large, solid state silicon integrating array with multiple output channels and off-the-focal-plane analog, time domain, background removing filters. A second design would use the same technology, but the sensor would consist of up to four virtually independent focal plane arrays. This design reduces the areal coverage of each detector, thus narrower interference filters could be utilized. Superior performance would be realized at a probable increase in cost. The final design would use a three-dimensional focal plane in order to perform background removal at the focal plane. Superior performance would be achieved along with reduced weight and power requirements. Unfortunately, this focal plane technology is still under development.

The scientific justification for the lightning mapper has been strengthened significantly during the past year. For example, we have demonstrated the ability of an optical lightning detector to reveal strong convective regions embedded within large storm systems. We have further demonstrated that the evolution of lightning activity strongly reflects overall storm development, thus the lightning mapper should be an excellent now-casting tool. The interest of the meteorological community in a lightning mapper has increased significantly during the past years. The scientific support is expanding.

FOCUS OF CURRENT RESEARCH ACTIVITIES:

The prime focus continues to be the analysis of the U2 lightning data, both to study the detailed characteristics of lightning as detected from above cloud top and to understand lightning activity in the context of overall storm development.

Another major effort is directed toward establishing the adequacy of analog time domain filtering for meeting the lightning mapper background signal removal requirements. The present approach consists of developing and testing filter algorithms with a computer operating on U2 data. After an optimized algorithm has been developed, it will be implemented in hardware and tested on the same U2 data.

PLANS FOR FY-86:

- 1) Continue scientific research focused on providing the quantitative, detail rationale necessary to provide for a lightning mapper new start.
- 2) Conduct a U2 based lightning research campaign during the SPACE/MIST field program. The U2 instrument package will be enhanced with the addition of electric field mills and conductivity probes in order to determine the total current flow above thunderstorms and the strength of the electrical generator.
- 3) Instrument the nose section of the ER2 so that coordinated lightning, passive microwave, and thermal infrared measurements can be made during the SPACE/MIST program. This effort could form the basis for a pre-SASE mission.
- 4) Initiate the development of a large custom focal plane array.

LIST OF PUBLICATIONS:

Christian, H. J., W. W. Vaughan and J. C. Dodge, 1984: A Technique for the Detection of Lightning from Geostationary Orbit. Preprints, Conf. on Satellite Meteorology/Remote Sensing Applications, Am. Meteor. Soc.

Christian, H. J., R. L. Frost and S. J. Goodman, 1984: Optical Characteristics of Lightning as Measured from Above Cloud Tops. Preprints, VII International Conf. on Atmospheric Electricity, Am. Meteor. Soc., Vol. 4.

Christian, H. J., W. W. Vaughan, and J. C. Dodge, 1984: The Detection and Location of Lightning from Sapce. Preprints, VII International Conf. on Atmospheric Electricity, Am. Meteor. Soc., Vol. 4.

Goodman, S. J., H. J. Christian, N. D. Rust, D. R. MacGorman and R. T. Arnold: Simultaneous Observations of Cloud to Ground Lightning Above and Below Cloud Tops. Preprints, VII International Conference on Atmospheric Electricity, Am. Meteor. Soc.

Christian, H. J., and S. J. Goodman, 1985: Observations of Lightning from Above Clouds. Submitted to JGR.

Goodman, S. J., H. J. Christian, W. D. Rust and R. T. Arnold, 1985: Optical Characteristics of Cloud-to-Ground Lightning Observed from Above Clouds. Submitted to JGR.

Goodman, S. J., H. J. Christian, W. D. Rust, D. R. MacGorman, and R. T. Arnold, 1985: Lightning Observations Above and Below Clouds: Comparisons with Storm Development, Radar and Satellite Data. Submitted to JGR.

Robertson, F. R., G. S. Wilson, H. J. Christian, S. J. Goodman, G. H. Fichtl and W. W. Vaughan, 1984: Atmospheric Science Experiments Applicable to Space Shuttle Spacelab Missions. Bull. Am. Meteor. Soc., Vol. 65, pp. 692-700.

88521-08N

N86-15787

TITLE: Space Shuttle/Mesoscale Lightning Experiment

INVESTIGATORS: Otha H. Vaughan, Jr., ED43
NASA/Marshall Space Flight Center
Huntsville, AL 35812

B. Vonnegut, ES 323
State University of New York at Albany
Albany, New York 12222

Marx Brook, R&D
New Mexico Institute of Mining and Technology
Socorro, New Mexico 97801

SIGNIFICANT ACCOMPLISHMENTS IN FY-85:

This experiment was conceived by the three investigators and a proposal was submitted through MSFC Project Office to NASA Headquarters. Headquarters approved the proposal in late 1984 and coordination was finally established with Johnson Space Center Shuttle payload integration people in February 1985. A payload integration plan (PIP) is now being developed with JSC integration personnel which covers management, structural thermal, electrical power/avionics, training, ground operations, safety requirements, etc., in support of this experiment. A draft of the PIP will be completed in late May 1985. If a Shuttle flight can be identified, we hope to conduct the experiment in the late summer or fall of 1985. Some preliminary TV lightning data has been collected by Shuttle crews on 41D and 51D and we are doing an analysis of it.

PLANS FOR FY-85:

Additional flights will be conducted to obtain data on Mesoscale Lightning Observations.

RECOMMENDATIONS FOR NEW RESEARCH:

We will continue to study how to improve the data collection using the onboard TV cameras. By more interaction with the crews who have used the TV cameras to obtain TV of lightning, we are planning to optimize the crew time and have better TV camera operations management to produce more useful data. As the crews are better trained in the use of the gain control settings and/or camera iris operations, the quality of the TV data will be improved.

PUBLICATIONS:

Vonnegut, B., O. H. Vaughan, Jr., M. Brook and P. Krehbiel, September 1984: Mesoscale Observations of Lightning from Space Shuttle. TM 86451.

78721-08W

N86-15788

TITLE: Optical Characteristics of Lightning and Thunderstorm Currents

INVESTIGATORS: E. Philip Krider
Inst. of Atmospheric Physics
University of Arizona
Tucson, AZ 85721

Richard J. Blakeslee
Code ED-43
NASA Marshall Space Flight Center, AL 35812

ACCOMPLISHMENTS:

We have determined that lightning can be used to determine the diurnal variations of thunderstorms, i.e., storms that produce audible thunder, and that these variations are also in good agreement with diurnal variations in rainfall and convective activity.

Measurements of the Maxwell current density, J_m , under active thunderstorms show that this physical quantity is quasi-steady between lightning discharges and that lightning does not produce large changes in J_m . Maps of J_m show contours of iso-current density that are consistent with the locations of radar echos and the locations of where lightning has altered the cloud charge distribution.

PLANS FOR FY-86:

We hope to examine in detail the radiative efficiency of lightning-like laboratory sparks, triggered lightning, and if possible, natural discharges. We also plan to study the effects of clouds and multiple scattering on the light produced by lightning and to investigate the relationship between optical lightning and the Maxwell current densities under thunderstorms.

PUBLICATIONS:

Maier, L. M., E. P. Krider, and M. W. Maier: Average Diurnal Variation of Summer Lightning Over the Florida Peninsula. Mon. Wea. Rev., Vol. 112, pp. 1134-1140, 1984.

Krider, E. P. and R. J. Blakeslee: The Electric Currents Produced by Thunderclouds. To be published in J. Electrostatics, 1985.

Maier, L. J. and E. P. Krider: The Charges Neutralized by Cloud-to-Ground Lightning in Florida. Submitted to J. Geophys. Res., December 1984.

TITLE: Optical Characteristics of Lightning

INVESTIGATOR: Steven J. Goodman
USRA Visiting Scientist Program
NASA/MSFC ED43
(205) 453-1325

SIGNIFICANT ACCOMPLISHMENTS TO DATE IN FY-85:

1) A study of the optical characteristics of cloud-to-ground discharges and how they compare with intracloud flashes has been completed. Time resolved optical (7774A) and electric field-change waveforms were measured above clouds from a U2 airplane coincident with ground-based measurements of lightning. The optical pulse trains are studied for within and between flash variability. Specifically, for each flash we examine the 10, 50 (full width half maximum), and 90 percent pulse widths; the 10-10, 10-50, 10-90, and 10-peak percent amplitude rise times; the radiances (optical power densities); radiant energy densities; and pulse intervals. The optical pulse characteristics of first strokes, subsequent strokes, the intracloud components of cloud-to-ground flashes and intracloud flashes as viewed from above cloud are shown to exhibit very similar waveshapes, radiances and radiant energy densities.

Descriptive statistics on these pulse categories have been tabulated for 25 visually confirmed cloud-to-ground flashes (229 optical pulses) and 232 intracloud flashes (3126 optical pulses). The mean radiance and energy density is $1.28 \pm 1.91 \times 10^{-2} \text{ W} \cdot \text{m}^{-2} \cdot \text{sr}^{-1}$ and $6.07 \pm 7.29 \times 10^{-6} \text{ J} \cdot \text{m}^{-2} \cdot \text{sr}^{-1}$, respectively for ground discharges; $1.61 \pm 2.78 \times 10^{-2} \text{ W} \cdot \text{m}^{-2} \cdot \text{sr}^{-1}$ and $6.55 \pm 12.8 \times 10^{-6} \text{ J} \cdot \text{m}^{-2} \cdot \text{sr}^{-1}$ for cloud flashes. First strokes optical pulses are seldom the most radiant or energetic pulses produced by ground discharges. The intracloud components of cloud-to-ground flashes typically produce the optical pulses with the largest peak radiance within a cloud-to-ground flash, but subsequent strokes are more likely to have the largest energy densities and most complex pulse shapes. On average, intracloud flashes have almost twice as many optical pulses as the ground discharges. Also, the inter-pulse time is typically 70 percent longer for ground discharges than for the cloud flashes. There is often a great deal of pulse structure variation within and between flashes. Multiple stroke cloud-to-ground flashes are difficult to distinguish uniquely from intracloud flashes based solely on their optical signature above cloud, but single stroke cloud-to-ground flashes appear to have a unique single pulse optical signature.

2) A companion study of lightning observations above and below cloud in storms, storm complexes, and mesoscale convective systems has also been completed. We have compared the mapping of total lightning activity from above clouds with ground-based measurements and storm evolution. Although the total (IC + CG) lightning activity is the more representative indication of thunderstorm growth and decay, the ground strike data can be used to locate, diagnose, and track storm evolution in a number of instances. The spatial clustering of the CG strikes appears to be related to the intensity of the thunderstorm. Ground strike densities greater than 10×10^{-2} strikes km^{-2} over 15 minute time intervals are common in intense Great Plains

thunderstorms. A large separation distance (>40 km) between the strike points and optical emissions from ground discharges have been observed in MCS's and may occur in other large storm systems. Although the lightning observations above and below cloud can locate thunderstorms embedded in cirrus and stratus cloud decks, the ability to detect optical emissions from space may better delineate the quantity and intensity of lightning associated with convective cells embedded in storm complexes and define the cell location even though the cell is obscured from conventional GOES satellite detection and tracking by anvil material. Lightning data offers the atmospheric scientist new insight into the characteristics of convection in MCC and MCS-type storm systems. The lightning data may also prove to be useful in convective parameterization schemes and for mesoscale numerical model verification.

3) A review of lightning observations made above clouds by high altitude airplane (U2), rockets, and spacecraft has been completed. The major conclusions of this study are (1) the optical energy of both cloud-to-ground and intracloud lightning measured from above cloud top is not significantly different from measurements made of cloud-to-ground discharges from beneath storms; (2) the optical pulse rise times are slower and pulse widths are broader, primarily as a result of multiple scattering within the cloud; and (3) the spectral characteristics of the neutral emission lines are similar for ground based and airborne observations.

FOCUS OF CURRENT RESEARCH ACTIVITIES:

Comparisons of lightning observations above and below cloud with storm structure and evolution will continue. An investigation comparing the effects of lightning on the ionosphere and magnetosphere has recently begun. Ground based and U2 measurements are being compared with photometer, particle and wave data collected by the polar orbiting S81-1 and Dynamics Explorer satellites.

PLANS FOR FY-86:

Prepare the LLP direction finder sites for the space program and continue the existing research effort.

RECOMMENDATIONS FOR NEW RESEARCH:

Evaluate the use of lightning data for modelling the precipitation of trapped electrons from the magnetosphere.

During the space field program we hope to schedule data acquisition from the DE and P78-1 (particle instruments) satellites in conjunction with ER2/U2 and ground based lightning observations.

LIST OF PUBLICATIONS SINCE JUNE 1984:

Goodman, S. J., H. J. Christian, W. D. Rust, D. R. MacGorman, and R. T. Arnold, 1985: Lightning Observations Above and Below Clouds: Comparisons with Storm Development, Radar and Satellite Data. Submitted to JGR.

00721-28N

Goodman, S. J., H. J. Christian, W. D. Rust and R. T. Arnold, 1985: Optical Characteristics of Cloud-to-Ground Lightning Observed from Above Clouds. Submitted to JGR.

Christian, H. J. and S. J. Goodman, 1985: Observations of Lightning from Above clouds. Submitted to JGR.

Robertson, F. R., G. S. Wilson, H. J. Christian, S. J. Goodman, G. H. Fichtl and W. W. Vaughan, 1984: Atmospheric Science Experiments Applicable to Space Shuttle Spacelab Missions. Bull. Am. Meteor. Soc., Vol. 65, pp 692-700.

TITLE: Airborne Atmospheric Electricity Experiments

INVESTIGATOR: Richard J. Blakeslee
Atmospheric Sciences Division
NASA/Marshall Space Flight Center, AL 35812
(205) 453-2463

SIGNIFICANT ACCOMPLISHMENTS TO DATE IN FY-85:

During the 1984 U2 spring flight program, lightning spectra were measured in the wavelengths from 380 nm to 900 nm with a temporal resolution of 5 ms. With this capability, we simultaneously acquired both visible and near-infrared lightning spectra on a pulse to pulse basis, so that the spectral variability within a flash, as well as flash to flash variations, can be studied. Preliminary results suggest that important variations do occur, particularly in the strengths of the hydrogen and singly ionized nitrogen emission lines. Also, the results have revealed significant differences in the integrated energy distributions between the lightning spectra measured above clouds and the spectral measurements of cloud-to-ground lightning made at the ground. In particular, the ratio of the energy in the near-IR to that in the visible is around 1 to 2 for cloud top spectra versus about 1/3 for surface observations (Orville and Henderson, JAS, Vol. 41, pp. 3180-3187, 1984).

FOCUS OF CURRENT RESEARCH ACTIVITIES:

1) Detailed analyses of the 1984 lightning spectral data is being conducted. This data should provide improved understanding about the optical transmission properties of thunderclouds and the physics of the lightning discharge process.

2) Efforts continue on developing and testing background signal removal algorithms using U2 spectrometer and optical array sensor day-flight data sets. The goal of this research is to develop an algorithm satisfying Lightning Mapper Sensor requirements.

3) Using improved analysis programs, we will extend the cloud top optical pulse statistics to include the 1984 data. We also plan to determine (jointly with M. Brook) whether it is really possible to distinguish between cloud-to-ground and intracloud flashes from optical signals alone.

PLANS FOR FY-86:

We plan to install field mills and conductivity probes on the U2 for the 1986 field program to estimate the Maxwell current density over the tops of thunderstorms. From these measurements, we may be able to establish relationships between a storm's electric current output and the cloud top optical emissions.

PUBLICATIONS:

Krider, E. P.: The Electric Currents Produced by Thunderclouds. To be published in J. Electrostatics, 1985.

The Electric Currents Under Thunderstorms at the NASA Kennedy Space Center. With E. P. Krider, VIIth Int. Conf. on Atmos. Electricity, Albany, New York, June 3-8, 1984.

The Electric Current Densities Beneath Thunderstorms. Ph.D. Dissertation, University of Arizona, Tucson, 1984.

AIRBORNE/GROUND-BASED DOPPLER LIDAR WIND RESEARCH

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TITLE: Airborne Doppler Measurements of the Central California Extended Sea Breeze

INVESTIGATOR: John J. Carroll
Department of Land Air and Water Resources
University of California
Davis, California 95616
(916) 752-3245

FY-85 ACCOMPLISHMENTS:

One data acquisition flight was executed in the late summer of 1984. The flight paths were designed to obtain measurements of the extended sea breeze penetration into the central valley of California over several hours. Data from this flight are being processed at MSFC prior to release to us for analysis.

CURRENT ACTIVITY:

Active research on this project is to begin in summer 1985. Funding for this work has not been allocated as yet. The reason for the delay in commencing this effort is in part to allow initial evaluation of the lidar data quality at MSFC and to allow the assessment of the airborne system performance.

PLANS FOR FY-86:

The primary objective of this project is the mapping of the complex mesoscale flow associated with the intrusion of marine air into the central valley of California. This analysis seeks to delineate the mass flow through several passes in the coastal mountains and the pattern of diffluence within the valley. Additional information in the form of rawinsonde data and hourly surface meteorological data will be employed to augment this analysis. This work is expected to yield improved understanding of the kinematics and dynamics of these types of flows.

The final product of the analysis of these data will be maps of the wind field at the surface and at the flight level (1500 ft) valid at different times during the afternoon of the flight. Hourly surface maps of temperature and pressure will also be prepared. These latter will be especially useful for examination of the forces acting on air parcels as they travel through the region. These analyses will be well suited for verification of primitive equation based mesoscale models. Especially important is the fact that the spacial resolution in the lidar derived wind field is greater than that commonly found in such models. This then gives us the unique opportunity to compare details of the model predicted wind field as well as to evaluate subgrid scale parameterizations in the models.

The spacial detail in the lidar derived wind fields is also very important in several applied problems. Among these are the validation of objective wind field analysis techniques such as diagnostic mass conserving wind field and trajectory models. These in turn are critical tools in the analysis and prediction of the transport and dispersion of airborne contaminants.

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Recommendations for new research will await the results of the current study.

RECENT PUBLICATIONS:

On the Accuracy of Wind Measurements Using Airborne Doppler Lidar.
Revised manuscript submitted to the J. Atmos. & Ocean. Tech., April 1985.

TITLE: Analysis of Doppler Lidar Data

INVESTIGATOR: Jeffry Rothermel
USRA Visiting Scientist
Atmospheric Sciences Division
NASA/ED43
Marshall Space Flight Center, AL 35812
(205) 453-4219

SIGNIFICANT ACCOMPLISHMENTS:

1. JAWS Wind Measurements: Dual Doppler lidar analyses of data taken by MSFC and NOAA/WPL pulsed lidars demonstrated feasibility of deriving wind fields from coordinated lidar scans. Limited case histories of thunderstorm outflows were obtained. Co-located comparison between MSFC lidar and NCAR 5.5 cm radar demonstrated desirability of lidar in cases of marginal radar reflectivity in clear air and low-elevation scans. Results from JAWS participation are more fully described in a paper to appear in the Journal of Atmospheric Oceanic Technology.

2. Ground-based Measurements at MSFC: Analysis continued on back-scattered intensity and velocity measurements made from April 1983 to February 1984. A slant path method was used to calculate vertical profiles of volumetric backscatter and adsorption in the lower troposphere. High-quality VAD scans were identified as candidates for investigating feasibility of calculating horizontal motion fields using single Doppler lidar.

3. 1984 Airborne Doppler Experiments: Activities during FY-85 also included participation in Fall 1984 airborne Doppler lidar flight experiments. Preliminary data review was begun using McIdas system.

FOCUS OF CURRENT RESEARCH:

1. Analysis of backscatter and absorption profiles continues. Focus is on understanding spatial and temporal variations, as well as frequency distribution, of backscatter at several tropospheric levels. A paper describing this work is nearly completed. Results from this study provide input to evaluation of "clean/dirty" air mass hypothesis of aerosol distribution (see report by D. A. Bowdle, herein).

2. Assistance is being given to preparation of a comprehensive, global backscatter measurement plan.

3. Analysis of data from Fall 1984 flight experiments is just beginning. Work has begun on preprocessing data to minimize errors due to electro-optic modulator malfunction during flights.

PLANS FOR FY-86:

1. Perform backscatter comparison between MSFC and NOAA/WPL 10.6 μm pulsed lidars using JAWS data.

2. Demonstrate feasibility of retrieving horizontal motion field from single Doppler lidar scans, using data from JAWS and MSFC.

3. Continue analysis of wind data from Fall 1984 flights.
4. Participate in planning and execution of wind measurement experiments with 10.6 μm pulsed system at NSSL, Oklahoma and SPACE, Huntsville.
5. Participate in final planning of comprehensive global backscatter assessment experiment.

PUBLICATIONS PREPARED SINCE JUNE 1984:

Rothermel, J., 1985: Coherent Lidar Measurements of Backscatter Transmission Loss Profiles. Technical Digest, Topical Meeting on Optical Remote Sensing of the Atmosphere, Incline Village, Nevada, Optical Soc. Amer.

Rothermel, J. and E. M. Agee, 1985: Numerical Simulation of Atmospheric Convective Scaling. J. Atmos. Sci., accepted pending revision.

Rothermel, J. and W. D. Jones, 1985: Ground-based Measurements of Atmospheric Backscatter and Absorption Using Coherent CO_2 Lidar. Applied Optics, to be submitted.

Rothermel, J., C. Kessinger, and D. L. Davis, 1985: Dual Doppler Lidar Measurements of Winds in the JAWS Experiment. J. Atmos. Oceanic Tech., Vol. 2, to appear in June issue.

TITLE: Airborne Doppler Lidar Activities

INVESTIGATORS: D. R. Fitzjarrald
Atmospheric Sciences Division
Mail Code ED43
Marshall Space Flight Center, AL 35812
(205) 453-3104

J. W. Bilbro
Guidance, Control, and Optical Systems Division
Mail Code EG23
Marshall Space Flight Center, AL 35812
(205) 453-1597

SIGNIFICANT ACCOMPLISHMENTS TO DATE IN FY-85:

1984 Airborne Doppler Lidar Research Flights: During August and September 1984, 20 research flights were conducted by the CV990 with the MSFC Airborne Doppler Lidar installed. Nine of these flights were dedicated to the Lidar project. Excellent data were obtained in the Carquenez Strait downwind of San Francisco Bay, showing the divergence of the flow as it passes into the Central Valley. The data clearly show the horizontal and vertical structure of the wind flow in the pass region and adjoining parts of the Central Valley. Data were also obtained in the vicinity of Mount Shasta in northern California, showing the flow in the lee of the isolated mountain. Preliminary analyses of these flights using the McIDAS interactive graphics system have been accomplished, and procurements have been initiated for detailed scientific analyses.

A partial failure of a crucial optical component resulted in contamination of a portion of the wind data that were obtained in the Mount Shasta and subsequent flights. Analyses are underway to attempt reconstruction of the data to minimize the effects of the failure. Data were obtained in conjunction with a microwave wind profiler at Penn State University. It is expected that data reconstruction will be of use in this case. Procurement has been initiated for scientific analyses of these results.

The improved airborne Lidar system performed well. In most of the research flights a large number of different scan angles were used to obtain the vertical structure of the wind fields being investigated. Improved data display and recording allowed significantly better experiment control than in the 1981 flights. Signal return was generally adequate to make good wind determinations in the boundary layer. Methods for insuring proper alignment of the scanner were developed and used.

PLANS FOR FY-86:

Planning for 1986 Experiments: Proposals have been received and planning initiated for participation in the Space/Mist experiment and in the NOAA/NSSL spring severe storms effort. Capitalizing on the experience and improvements of the 1984 airborne Lidar system and using the various data available in the cooperative experiments will make possible a significant science return from this effort. The research topics to be investigated will include the structure of severe storms at NSSL. Arc cloud investigations

and moisture and momentum flux measurements will be the primary topics during the Space/Mist experiments, along with other cooperative investigations for which the detailed wind structure measurements will be useful.

RECOMMENDATIONS FOR NEW RESEARCH:

Consideration should be given to participation by the Airborne Doppler Lidar in upcoming field programs such as the STORM program. It is recommended that the laser transmitter be upgraded before such additional wind measuring experiments are undertaken.

THE MESOSCALE ENVIRONMENT AND MODELING

TITLE: Response of the Mesoscale Atmosphere to Diabatic Heating

INVESTIGATOR: Franklin R. Robertson
Atmospheric Sciences Division, ED43
Marshall Space Flight Center, AL 35812
(205) 453-5218

SIGNIFICANT ACCOMPLISHMENTS IN FY-85:

A study has been initiated to determine the influence of convective latent heat release/diabatic heating on the production of kinetic energy during AVE/SESAME I. The heating fields used are those derived from the diagnostic cumulus parameterization technique developed in previous work (see FY84 NASA/MSFC Atmospheric Processes Review Document). The primary focus has been on the relative importance of thermally forced modification of the wind field through thickness and height gradient changes versus inertial-advective effects via the diabatic component of vertical motion. Preliminary results have shown that because of the strong vertical shear over the convective region, ageostrophic response is primarily caused by the latter process.

The diagnostic parameterization of convective heating has been extended for use in conjunction with satellite precipitation estimates in data-poor oceanic regions. An initial application was made to a mesoscale convective system embedded in the South Pacific convergence zone. Comparison to the heating field diagnosed as a residual in the thermodynamic equation using the ECMWF III-b analyses showed that the methodology will be useful in explaining the observed heating fields and determining the relative contribution of moist processes to the total diabatic heating.

FOCUS OF CURRENT RESEARCH:

Research activities are now concentrated in the following areas:

- 1) Determining the sensitivity of vertical heating profiles to partitioning of gridscale versus convective precipitation.
- 2) Assessing the possible effects of incorrect analyzed gridscale vertical motions on residuals in the heat budgets computed with the ECMWF III-b data sets.

PLANS FOR FY-86:

- 1) Finish AVE/SESAME analysis and submit for publication.
- 2) Complete application to South Pacific convergence zone convective events.
- 3) Examine application to East Coast cyclones in anticipation of GALE experiment.
- 4) Begin application to SPACE field measurements.

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PUBLICATIONS AND CONFERENCE PRESENTATIONS:

Miller, B. L., D. G. Vincent and F. R. Robertson, 1985: Precipitation Estimates for the Tropical South Pacific During FGGE, 10-18 January 1979. Preprints Volume, 16th Conference on Hurricanes and Tropical Meteorology, Houston, TX, May 1985.

Robertson, F. R., 1985: Estimation of Rainfall in Extratropical Cyclones Using GOES IR Imagery, 5th Extratropical Cyclone Workshop, Port Deposit, MD, April 1985.

TITLE: Mesoscale Ageostrophic Circulations Associated with Baroclinic Jet Streaks

INVESTIGATOR: Donald R. Johnson
Space Science and Engineering Center
University of Wisconsin - Madison
Madison, Wisconsin 53706
(910) 286-2771

PUBLICATIONS:

In regard to research completed, the following is a complete list of publications and theses sponsored through the support of the NASA Severe Storms Research Project under NASA contract NAS8-33222:

Keyser, D. A., 1981: Effects of Diabatic Heating on the Ageostrophic Circulation of an Upper Tropospheric Jet Streak. M.S. Thesis, University of Wisconsin-Madison, 121 pp.

Keyser, D. A., and D. R. Johnson, 1983: Effects of Diabatic Heating on the Ageostrophic Circulation of an Upper Tropospheric Jet Streak. NASA Contractor Rep. 3497 (1982), prepared for Marshall Space Flight Center under Contract NAS8-33222, (NTIS 8216658), 121 pp.

Schlesinger, R. E., L. W. Uccellini, and D. R. Johnson, 1983: The Effects of the Asselin Time Filter on Numerical Solutions to the Linearized Shallow-Water Wave Equations. Mon. Wea. Rev., Vol. 111, pp. 455-467.

Johnson, D. R., and L. W. Uccellini, 1983: A Comparison of Methods for Computing the Sigma Coordinate Pressure Gradient Force for Flow Over Sloped Terrain in a Hybrid Theta-Sigma Model. Mon. Wea. Rev., Vol. 111, pp. 870-886.

Keyser, D. A., and D. R. Johnson, 1984: Effects of Diabatic Heating on the Ageostrophic Circulation of an Upper Tropospheric Jet Streak. Mon. Wea. Rev., Vol. 112, pp. 1709-1724.

Johnson, D. R., 1984: The Inducement of Planetary Boundary Layer Mass Convergence Associated with Varying Vorticity Beneath Tropospheric Wind Maximum. Presented at Nowcasting II, The Second International Symposium on Nowcasting, Norrkoping, Sweden, September 3-7, 1984. Published in Proceedings of the Second International Symposium on Nowcasting, Norrkoping, Sweden, by the European Space Agency (ESA SP-208), pp. 41-46.

Black, T. L., 1984: Numerical Experiments of Jet Streak Ageostrophic Circulations Using Pseudo-Geostrophic Initialization and Perspectives. Ph.D. Thesis, University of Wisconsin-Madison, 185 pp.

TITLE: Analysis of Satellite Data for Sensor Improvement (Detection of Severe Storms from Space)

INVESTIGATOR: T. Theodore Fujita
The University of Chicago
Chicago, Illinois 60637
(312) 962-8112

SIGNIFICANT ACCOMPLISHMENTS FOR FY-85:

1. Climatological study of downbursts in the six-state area. These states are Arkansas, Louisiana, Tennessee, Mississippi, Alabama, and Georgia.
2. Studies of the Huntsville area microbursts which are (a) Huntsville boat microburst on July 7, 1984, and (b) Decatur houseboats microburst on August 1984.
3. Preliminary design of the MIST/SPACE/FLOWS mesonet including five (5) Doppler radars.
4. Completion of "The Downburst" book.

PLANS FOR FY-86:

Operation of the COHMEX network serving for the three (3) component projects, SPACE (Satellite Precipitation and Cloud Experiment), MIST (Microburst and Severe Thunderstorm), and FLOWS (FAA Lincoln Lab Operational Weather Studies), each of which is to be conducted under the direction of the principal investigators assigned to each project.

RECOMMENDATIONS FOR NEW RESEARCH:

It is recommended that the three component projects listed above will be conducted in the Huntsville area during the months of June and July 1986.

PUBLISHED PAPERS IN FY-85:

Wakimoto, R. M., 1984: Forecasting Dry Microburst Activity Over the High Plains. Preprint, 10th Conf. on Weather Forecasting and Analysis, Clearwater Beach, January 25-29, 1984, pp. 537-542, Amer. Meteor. Soc.

Wakimoto, R. M., 1984: Clear Air Mesocyclone During the JAWS Project. Preprint, 22nd Conf. on Radar Meteorology, Zurich, Sept. 10-13, 1984, pp. 476-481, Amer. Meteor. Soc.

Fujita, T. T., 1984: Review of the History of Mesometeorology and Forecasting (Chapter 1). SMRP Research Paper 208.

Stiegler, D. J., 1984: Mesoscale Structure of Hurricane Alicia. SMRP Research Paper 209.

Fujita, T. T., 1985: The Downburst book, hard-cover, color, SMRP Research Paper 210, 122 pp.

TITLE: Severe Storm Detection with Passive 37 GHz Observations

INVESTIGATORS: Roy W. Spencer
USRA Visiting Scientist
ED43
NASA/Marshall Space Flight Center, AL 35812

Michael R. Howland and David W. Martin
Space Science and Engineering Center
1225 West Dayton Street
Madison, Wisconsin 53706

RESEARCH OBJECTIVES:

To determine the information content of satellite passive 37 GHz brightness temperatures on the severity of thunderstorms, through the measurement of the attenuation (scattering) signature of precipitation.

SIGNIFICANT ACCOMPLISHMENTS:

The severe storm detection potential of satellite-observed passive 37 GHz radiances was evaluated by comparing Nimbus-7 Scanning Multi-channel Microwave Radiometer (SMMR) data to reports of severe weather contained in the NSSFC severe weather log for calendar years 1979 and 1980 over the United States east of the Rocky Mountains. Heavy thunderstorms have a characteristic signature in the form of localized very low 37 GHz T_B from scattering by precipitation-size ice particles (thick cirrus being transparent at this frequency).

The local noon and midnight "snapshots" taken by the SMMR on alternating days (with incomplete areal coverage of the U.S. on any given day) were scanned to find cases of strong scattering by precipitation, revealed by large differences between the 18 and 37 GHz brightness temperatures, the 37 GHz T_B being at least 20°C lower than the 18 GHz T_B . The value of the 37 GHz T_B was then compared to severe weather reports within one hour of the SMMR observation time, in the vicinity of the SMMR-observed storm. It was found that the degree to which the T_B were lowered was a fairly good indicator of the probability that the storm was severe. Of 263 storms observed by the SMMR during 1979 and 1980, 54 percent had severe weather associated with them for a T_B below 203 K, while 8 percent of those above this threshold were severe. This led to a probability of detection of 0.54, a false alarm ratio of 0.45, and a critical success index of 0.375. For 1980 alone, these numbers improved significantly to a POD of 0.60, FAR of 0.29, and a CSI of 0.48.

While competitive with published skills for radar detection of severe storms, these skills are difficult to compare to those of radar because (1) radar offers nearly continuous monitoring while the SMMR observes any given storm for only an instant; (2) radar methods are typically derived only during the severe weather season and in areas prone to severe thunderstorms, whereas this study involved all seasons and the eastern two-thirds of the U.S., and (3) the poor spatial resolution of the SMMR 37 GHz channels

(27 km) is not optimum to observe cores of thunderstorms. In view of these differences and the results of the SMMR-severe reports comparisons, there is sufficient evidence to pursue the possibility that geostationary passive microwave observations would be an important severe storm detection tool in the future, especially if synthetic aperture techniques or other technological improvements allow imaging at high spatial resolutions at frequencies low enough to allow the monitoring of precipitation-induced effects only (generally below 50 to 90 GHz). Alternately, high frequency measurements (near 200 GHz) might provide information beyond what is currently available with infrared observations, though at the expense of poorer resolution.

CURRENT RESEARCH:

A case study of intense convection is being carried out with comparisons between SMMR T_B and time lapse WSR-57 radar data to better determine height and types of precipitation hydrometers responsible for the strong T_B signatures observed at 37 GHz.

FUTURE RESEARCH:

Additional comparisons will be made between SMMR T_B and severe weather reports subsequent to 1980.

RELEVANT PUBLICATIONS:

Spencer, R. W., W. S. Olson, W. Rongzhang, D. W. Martin, J. A. Weinman and D. A. Santek, 1983a: Heavy Thunderstorms Observed Over Land by the Nimbus-7 Scanning Multichannel Microwave Radiometer. J. Climate Appl. Meteor., Vol. 22, pp. 1041-1046.

Spencer, R. W., D. W. Martin, B. B. Hinton, and J. A. Weinman, 1983b: Satellite Microwave Radiances Correlated with Radar Rain Rates Over Land. Nature, Vol. 304, pp. 141-143.

Spencer, R. W., B. B. Hinton, and W. S. Olson, 1983c: Nimbus-7 37 GHz Radiances Correlated with Radar Rain Rates Over the Gulf of Mexico. J. Climate Appl. Meteor., Vol. 22, pp. 2095-2099.

Spencer, R. W., 1984: Satellite Passive Microwave Rain Rate Measurement Over Croplands During Spring, Summer, and Fall. J. Climate Appl. Meteor., Vol. 23, pp. 1553-1562.

Spencer, R. W., and D. A. Santek, 1985: Measuring the Global Distribution of Intense Convection Over Land with Passive Microwave Radiometry. To appear in July J. Climate Appl. Meteor.

Spencer, Roy W., 1985: An Improved Satellite Passive 37 GHz Method for Measuring Oceanic Rainfall. Submitted to J. Climate Appl. Meteor.

TITLE: Automated Mesoscale Winds Derived from GOES Multispectral Imagery

INVESTIGATORS: Gregory S. Wilson
Atmospheric Physics Branch, ED43
Atmospheric Sciences Division
Marshall Space Flight Center, AL 35812
(205) 453-5218

Robert J. Atkinson
General Electric Company
Huntsville, AL 35805

SIGNIFICANT ACCOMPLISHMENTS TO DATE IN FY-85:

An automated technique for extracting mesoscale winds from sequences of GOES VISSR image pairs has been developed, tested extensively, and configured for quasi-real time/research applications on the Atmospheric Sciences Division's research computing system.

The entire system of computer codes was successfully vectorized for execution on an array processor resulting in job turnaround in less than 1 hour.

An objective quality control system provides much greater than 99 percent accuracy in eliminating questionable wind estimates.

Dynamical analysis of cloud wind divergence has revealed temporally consistent convergence centers on the meso- β scale that are highly correlated with ongoing and future developing convective storms.

1) Technique Development

Since the cloud pattern displacement between image pairs is a function of both wind speed and image-pair separation time, a "first-guess" of the actual wind speed is made based upon a "guess" vertical wind profile and the height assignment.

The simplest form of height assignment for cloud winds involves positioning the wind estimate in the vertical at the location where the ambient air temperature equals the template temperature.

A profile of pressure height versus air temperature in gridded form at one degree latitude and longitude increments was obtained from simultaneous radiosonde observations. Using the infrared template temperature, the height was assigned by interpolation into the vertical temperature profile.

The first guess wind speed is then determined at the assigned height by interpolation in the vertical wind speed profile.

2) Diagnostic Evaluations

An independent McIDAS/WINCO file of manual wind vectors has been produced at the University of Wisconsin for comparison with the automatic winds to learn the strengths and weaknesses of each method.

Comparisons of results with manually tracked winds are outstanding both statistically and structurally. Automated winds generally have better spatial coverage and density, and have random error estimates ($\sim 0.9 \text{ ms}^{-1}$) half as large as the manual winds.

3) Real-Time/Research Testing

Real-time/research data from the MSFC McIDAS can be directly inserted into the automated hardware/software system and results displayed and filed by McIDAS, as demonstrated by the transfer of WINCO files, gridded files, and VAS image and navigation files.

FOCUS OF CURRENT RESEARCH ACTIVITIES:

A journal paper is under preparation describing the entire cloud winds systems, including its application to a severe thunderstorm case, utilizing only VISSR image data.

A major improvement in the system is underway involving the use of VAS imagery. Both "water vapor" winds and improved cloud height algorithms will be added to the current system and tested using special "rapid scan" VAS dwell imagery obtained in June 1984. Limited tracking has been accomplished using the 6.7μ channel.

PLANS FOR FY-85:

Integration, testing, and evaluation of the VAS multispectral imagery as part of the VISSR automated cloud wind system will be accomplished. These results will be submitted for journal publication, thereby ending this research activity. In addition, some of the VAS data processing techniques will be attempted on the MAMS data. The two moisture channels on the MAMS will be used along with window radiance measurement to quantitatively derive estimates of atmospheric precipitable water values.

RECOMMENDATIONS FOR NEW RESEARCH:

Since this study has shown the need for high resolution multispectral imagery (in ~ 8 spectral bands) at high time frequency (5-15 minutes), a feasibility study should be undertaken to examine the possibility of developing a dedicated Multispectral Atmospheric Mapping System (MAMS) for a stabilized geostationary spacecraft for the purpose of mapping atmospheric structure and determining both mesoscale and global winds.

Use of these research results by other NASA researchers and other Government agencies, i.e., NOAA, should be encouraged, particularly the use of automated water vapor winds for global problems.

PUBLICATIONS:

Wilson, G. A., 1984: Automated Mesoscale Wind Fields Derived from GOES Satellite Imagery. Preprints, Conf. on Satellite Meteorology/Remote Sensing and Applications, Clearwater Beach, FL, June 1984.

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TITLE: Satellite Passive Microwave Rain Measurement Techniques for Land and Ocean

INVESTIGATOR: Roy W. Spencer
Universities Space Research Association
Atmospheric Sciences Division/ED43
NASA/Marshall Space Flight Center, AL 35812

SIGNIFICANT ACCOMPLISHMENTS:

Multiseasonal rainfall has been found to be measurable over land with satellite passive microwave data, based upon comparisons between Nimbus 7 Scanning Multichannel Microwave Radiometer (SMMR) brightness temperatures (T_B) and operational WSR-57 radar rain rates. All of the SMMR channels (bipolarized 37, 21, 18, 10.7, and 6.6 GHz T_B) were compared to radar reflectivities for 25 SMMR passes and 234 radar scans over the U.S. during the spring, summer, and fall of 1979. It was found that the radar rain rates were closely related to the difference between 37 and 21 GHz T_B .

This result is due to the volume scattering effects of precipitation which cause emissivity decreases with frequency, as opposed to emissive surfaces (e.g., water) whose emissivities increase with frequency. Two frequencies also act to reduce the effects of thermometric temperature variations on T_B to a minimum. During summer and fall, multiple correlation coefficients of 0.80 and 0.75 were obtained. These approach the limit of correlation that can be expected to exist between two very different data sources, especially in light of the errors attributable to manual digitization of PPI photographs of variable quality from various operational weather radars not calibrated for research purposes. During the spring, a significantly lower (0.63) correlation was found. This poorer performance was traced to cases of wet, unvegetated soil being sensed at the lower frequencies through light rain, partly negating the rain scattering signal. This problem might be corrected with addition of a higher frequency (e.g. 85 GHz). These rather optimistic results are contrary to the views expressed in Atlas and Thiele (1981) and so provide hope for satellite passive microwave precipitation measurement over land in the future.

For rain over the ocean, most investigators (e.g. Wilheit, et al., 1977) attempt to relate the absorption characteristics of rain to a rate, because the rain emits at unit emissivity while the ocean is radiometrically cold ($\epsilon \sim 0.5$). At 19 GHz, this leads to a relationship between rain rate and T_B which is nonlinear (leading to underestimates of rain rate within a footprint) and which has very little dynamic range above 15 mm h^{-1} (at rates which half of oceanic rain falls). Instead, we took the 37 GHz scattering relationship derived over land (which is nearly linear) and extended it to the ocean environment. By utilizing the 37 GHz polarization information the highly polarized ocean can be separated from the slightly polarized rain, and the rate can then be measured. Excellent agreement has been found between the radar depiction of convection over the Gulf of Mexico and this 37 GHz bipolarization method.

CURRENT AND FUTURE WORK:

Work is continuing in the analysis of SMMR data to learn more about the multifrequency signature of precipitation over land and ocean, during various seasons and in different climatic environments. The 1986 launch of the DOD Special Sensor Microwave Imager (SSM/I) will allow the first comparisons between 85 GHz and lower frequency data for rain measurement.

REFERENCES:

Atlas, D., and O. W. Thiele, Eds., 1981: Precipitation Measurements from Space Workshop Report. NASA, Goddard Space Flight Center, Greenbelt, MD, 20771.

Wilheit, T. T., A. T. C. Chang, M. S. V. Rao, E. B. Rodgers, and J. S. Theon, 1977: A Satellite Technique for Quantitatively Mapping Rainfall Rates Over the Oceans. J. Appl. Meteor., Vol. 16, pp. 551-560.

RELEVANT PUBLICATIONS:

Spencer, R. W., W. L. Olson, W. Rongzhang, D. W. Martin, J. A. Weinman and D. A. Santek, 1983a: Heavy Thunderstorms Observed Over Land by the Nimbus-7 Scanning Multichannel Microwave Radiometer. J. Climate Appl. Meteor., Vol. 22, pp. 1041-1046.

Spencer, R. W., D. W. Martin, B. B. Hinton and J. A. Weinman, 1983b: Satellite Microwave Radiances Correlated with Radar Rain Rates Over Land. Nature, Vol. 304, pp. 141-143.

Spencer, R. W., B. B. Hinton, and W. S. Olson, 1983c: Nimbus-7 37 Ghz Radiances Correlated with Radar Rain Rates Over the Gulf of Mexico, J. Climate Appl. Meteor., Vol. 22, pp. 2095-2099.

Spencer, R. W., 1984: Satellite Passive Microwave Rain Rate Measurement Over Croplands During Spring, Summer, and Fall. J. Climate Appl. Meteor., Vol. 23, pp. 1553-1562.

Spencer, R. W., and D. A. Santek, 1985: Measuring the Global Distribution of Intense Convection Over Land with Passive Microwave Radiometry. To appear in July J. Climate Appl. Meteor.

Spencer, Roy W., 1985: An Improved Satellite Passive 37 Ghz Method for Measuring Oceanic Rainfall. Submitted to J. Climate Appl. Meteor.

TITLE: Remote Sensing of Severe Convective Storms

INVESTIGATORS: R. J. Hung
The University of Alabama in Huntsville
Huntsville, Alabama 35899
(205) 895-6077

R. E. Smith
Atmospheric Science Division
NASA/Marshall Space Flight Center, Alabama 35812
(205) 453-3101

G. S. West
Atmospheric Science Division
NASA/Marshall Space Flight Center, Alabama 35812
(205) 453-5218

SIGNIFICANT ACCOMPLISHMENTS TO DATE IN FY-84:

The Tibet Plateau significantly affects the initiation and development of heavy rainfall and severe storms in China, just as the Rocky Mountains influence local severe storms in the United States. Many rain-bearing synoptic systems in China originate over the Plateau, and then move eastward and northward causing excessively heavy rains and outbreaks of severe storms in eastern and northern China. In the First GARP Global Experiment (FGGE), the American Satellite GOES-1 was moved to the Indian Ocean at 58°E during the period of time from December 1, 1978 to November 30, 1979. The infrared and visible imagery from the GOES-1 Satellite over the Tibet Plateau were used to study the convective cloud development and the amount of rainfall over the Plateau area in comparison with that of the Rocky Mountains.

The study shows that the heavy rainfall in the Plateau area is usually preceded by a high growth rate of the convective clouds, followed by a rapid collapse of the cloud top. The study also shows that the tops of the convective clouds associated with heavy rainfall over the Plateau usually lie between the altitudes of the two tropopause which exist over the Plateau. There is good agreement between the collapsing of the cloud as observed from the satellite imagery, and the beginning of the rainfall observed by the ground stations and also between the dissipation of the cloud observed from the satellite infrared imagery, and the ending of the rainfall, observed by the ground stations. Comparison of the volumetric dissipation of clouds per unit area over the location of the ground station with the rainfall recorded at that station shows a linear relationship for rainfall amounts exceeding 8 mm. The ratio of observed rainfall at the ground station over the satellite observed cloud volume dissipation per unit area was also computed. The result shows that the ratio is almost constant with the value of 9.55 mm/(pixel · km/pixel) for rainfall amounts exceeding 15 mm; and the variation is less than 10 percent for rainfall amounts between 8 and 15 mm. Needless to say, further investigation is required to verify this ratio.

The temperature-height profile above the tropopause affects the potential energy storage of overshooting cloud tops penetrating above the tropopause. The maximum potential energy per unit volume, and maximum differences between cloud top and tropopause temperatures have been studied for

four cases of storms which produced 27 tornadoes. The study shows that the total potential energy storage for these storm clouds, ranged from 10^{12} to 10^{15} joules. It further shows that the potential energy per unit of volume is closely related to the Fujita scale of storm damage index. Once again, further investigation is needed to verify this conclusion.

FOCUS OF CURRENT RESEARCH ACTIVITIES:

The potential energy storage of overshooting cloud tops penetrating above the tropopause is different for the same difference between the cloud top temperature and the temperature at the tropopause if the ambient vertical temperature gradient above the tropopause is different. Potential energy per unit volume and the temperature difference between overshooting cloud top and the tropopause are closely related but not with a linear dependence.

Preliminary study shows that the total potential energy storage of overshooting cloud tops penetrating above the tropopause greatly affects the number of tornado touchdowns; while the intensity of the storms seem closely related to the amount of potential energy per unit volume stored in the overshooting cloud tops above the tropopause. Preliminary study seems to indicate a strong correlation between potential energy per unit volume and the Fujita scale of storm damage index. Current research activities are focused on verifying these results.

PLANS FOR FY-86:

Study of rapid-scan infrared imagery from a satellite shows that, during the inception and developing stages of clouds before they penetrate the tropopause, there are very few apparent differences between clouds which spawn a tornado and those which end as a thunderstorm. After penetration of the tropopause, the differences between the cloud systems with and without tornadic storms are more readily discernible using satellite observation (Hung, Dodge, and Smith, AIAA J., Vol. 21, pp. 1216-1224, 1983). In plans for FY-86, the dynamics of cloud formation and development will be simulated by cloud modeling during the inception and developing stages of the clouds before they penetrate the tropopause to study the mechanism of convective instability, local convergences of moisture and energy, which can make up the short coming from the satellite observation. We are planning to use the cloud model developed by the South Dakota School of Mines and Technology, currently available and operational on the computer system at NASA/MSFC.

In the FY-86 plans, in addition to our current research on prestorm environments using the Doppler soundings for gravity waves excitation mechanisms; rawinsondes for vertical winds, moisture and temperature profiles; and satellite infrared imagery for time-dependent cloud top temperature distributions, we will carry out numerical simulations of the life cycle of a cloud to study convective instability, triggering mechanisms and the mechanism of local energy concentration required to support the development of convective clouds.

RECOMMENDATIONS FOR NEW RESEARCH:

In the late spring and early summer of 1986, an experiment named Satellite Precipitation and Cloud Experiment (SPACE) under the sponsorship of NASA: Mesoscale Atmospheric Processes Research Program will be conducted in the Northern Alabama and Southern Tennessee area by the Atmospheric Sciences Division, NASA/MSFC. In collaboration with the SPACE project, our new research will include: (1) the cloud modeling study to determine and better understand how convective processes lead to cloud formation and produce severe convective storms using data from the SPACE project; (2) study of the coupling of lower and upper atmospheres through the investigation of the propagation characteristics of gravity waves excited by the convective processes of severe storm development; and (3) study of cloud formation, development, penetration of overshooting cloud tops above the tropopause, and collapsing of the cloud tops. This will be accomplished through the analysis of rapid-scan infrared imagery from the GOES to determine how the potential energy storage of the overshooting cloud tops produced by the convective processes affects the intensity of storms and its correlation with the characteristics of gravity waves excited by the convective processes.

PUBLICATIONS SINCE JUNE 1984:

Hung, R. J., Tsao, D. Y., and Smith, R. E.: Case Study of Pampa, Texas, Multicell Storms. *Pure and Applied Geophysics*, Vol. 121, pp. 1019-1034, 1984.

Hung, R. J., Liu, J. M., Tsao, D. Y., and Smith, R. E.: Relationship Between Convective Clouds and Precipitation Over the Qinghai-Xizang Plateau Area from Satellite Remote Sensing and Ground-Based Observations. *Int. J. Remote Sensing*, Vol. 6, pp. 217-237, 1985.

Hung, R. J., Liu, J. M., and Smith, R. E.: Infrared Sensing of Convective Clouds and Amount of Rainfall Over the Tibet Plateau Area. *Annales Geophys.*, in press, 1985.

Hung, R. J., and Smith, R. E.: Visualization of Convective Flow Patterns from Infrared Imagery Analysis. *Developments in Theoretical and Applied Mechanis*, Vol. 12, in press, 1985.

Hung, R. J., and Smith, R. E.: Computer Image Processing of U-Draft Motion and Severe Storm Formation Observed from Satellite. *Flow Visualization*, Vol. 3, pp. 686-693, 1985.

Hung, R. J., and Smith, R. E.: Computer Image Processing and Severe Storm Detection. *Intelligent Systems, Imaging Technology, and Software Engineering*, pp. 71-81, Northwestern University, Boston, MA, 1984.

Hung, R. J., and Smith, R. E.: Overshooting Cloud Top, Variation of Tropopause and Severe Storm Fromation. *Satellite Meteorology/Remote Sensing and Applications*, pp. 22-28, Am. Meteorological Soc., Boston, MA, 1984.

TITLE: LAMPS Software and Mesoscale Prediction Studies

INVESTIGATOR: Dr. D. J. Perkey
Department of Physics and Atmospheric Science
Drexel University
Philadelphia, PA 19104
(215) 895-2728

SIGNIFICANT ACCOMPLISHMENTS TO DATE IN FY-85:

The full-physics version of the LAMPS model has been implemented on the Perkin-Elmer computer at MSFC. In addition, LAMPS graphics processors have been rewritten to the run on the MSFC Perkin-Elmer and they are currently undergoing final testing.

Numerical experiments investigating the impact of convective parameterized latent heat release on the evolution of a precipitating storm have been performed and the results are currently being evaluated.

Space Science and Engineering Center personnel have been trained to run LAMPS model and graphics routines at NCAR in support of the VAS Cooperative Project.

FOCUS OF CURRENT RESEARCH ACTIVITIES:

Current efforts include the continued evaluation of the impact of initial conditions on LAMPS model results. This work will help define measurement requirements for future research field projects as well as for observations in support of operational forecasts.

Also, the impact of parameterized latent heat on the evolution of precipitating systems is continuing. This research is in support of NASA's proposed Earth Observation Mission (EOM).

PLANS FOR FY-86:

Develop methods of using satellite information, both radiance and moisture information, to enhance the initial state used in the LAMPS model.

PUBLICATIONS SINCE JUNE 1984:

Perkey, D. J., 1984: Mesoscale Modeling: Model Formulation. Preprints of the AMS Intensive Course on Mesoscale Meteorology and Forecasting, Vol. III, 42 pp.

Kalb, M. W., and D. J. Perkey, 1985: Sensitivity of a Mesoscale Model to Initial Specification of Relative Humidity, Liquid Water and Vertical Motion. To be presented at the Seventh AMS Numerical Weather Prediction Conference in Montreal, Que., Canada June 17-20, 1985.

TITLE: Mesoscale - Cloud Scale Simulation of Convective Response

INVESTIGATORS: Fred J. Kopp
USRA (Consultant)
South Dakota School of Mines
Rapid City, SD 57701
(605) 394-2291

Richard T. McNider
Johnson Environmental and Energy Center
The University of Alabama in Huntsville
Huntsville, AL 35899
(205) 895-6257

SIGNIFICANT ACCOMPLISHMENTS IN FY-85:

During the summer of 1984 as a visitor at the Marshall Space Flight Center, the two-dimensional cloud model was used to simulate the convective response in an environment predicted by a mesoscale model. The cloud model experiments were run on the mesoscale model environment predicted by the mesoscale model for the Texas Panhandle on April 24, 1982. Simulated soundings were taken from the mesoscale model environment at the simulated time of 2000Z or 1400 local time. These soundings were taken at locations that were 200, 300, 350, 375, 400, 500 and 600 kilometers from the western edge of the mesoscale model. Amarillo, Texas is located in approximately the center of the mesoscale grid or at 375 kilometers from the western end of the mesoscale model. These seven positions in the mesoscale model represented different regions of surface heating, convergence effects and topography. While topography is not simulated in the cloud model, the effect of the topography simulated in the mesoscale model did affect the convergence and mesoscale environment in that region and so this will affect the response of the cloud model to the sounding taken from that location. All of the cloud model runs were made with no ambient wind. Convergence values as function of height were taken from the mesoscale model up to 6 kilometers or so which was the top of the mesoscale models accurate predictions. A divergence layer was imposed at about 8 kilometers to compensate for the convergence at lower levels. This is needed to bring the vertical motions induced by the convergence at the lower layers back to zero otherwise the vertical motions would continue to the top of the cloud model grid. The layer of divergence simulated a linearly increasing and then decreasing divergence value to produce a realistic horizontal wind profile resulting from the divergence.

The cloud model simulated the convective activity for a period of about two hours with no further interaction with the mesoscale model. As a consequence any changes that occurred in the mesoscale environment during the cloud model's time period of simulation were not accounted for. Such effects have never been attempted with the cloud model in any case. The convergence was held constant over the period of the simulation also.

The results show a clear differential convective response due to the mesoscale model environment (Fig. 1). The thermals and eventual clouds are much stronger in the western panhandle of Texas where the clear skies allowed the sun to heat the surface and deepen the boundary layer.

Thermals induced in the eastern panhandle environment are very weak and never produce clouds due to the shallow boundary layer and stable atmospheric sounding. The most interesting region is the intense convergence zone in the center of the mesoscale model. In this region the boundary layer decreases in height from west to east. Two simulations are done in this region, case C and case D. Case C is on the west side of the maximum convergence where the depth of convergence is greater, while case D is one mesoscale grid point east of case C in the maximum convergence region but the depth of the convergence is less. Case D is also in a somewhat more stable environment. There is a significant difference in the response between these two cases. Case D is a very much weaker cloud. On the other hand the clouds in case A and B are not much different from case C although they are not as vigorous so the convergence has had an effect on the growth. Case E is one more mesoscale grid point to the east and does not even produce a cloud. Case E is in a much weaker convergence region and a more stable environment so its thermal quickly weakens.

The convective clouds are not as vigorous as the observed clouds. After the cloud model is started, no additional environmental changes that the mesoscale model may predict is included. Therefore the cloud model environment may be more stable than the actual environment. The wind shear present in the mesoscale model has not been included and may be of some importance.

FOCUS OF CURRENT RESEARCH ACTIVITIES:

During the summer of 1985, experiments on the initialization of the cloud model are planned to determine the effect of various initialization schemes on the subsequent development of convective clouds in the model.

PUBLICATIONS:

A Mesoscale - Cloud Scale Simulation of Convective Response. Report to NASA, 1984, 22 p.

McNider, R. T., F. J. Kopp, M. W. Kalb, and G. S. Wilson, 1985: Simulation of Mesoscale Convective Response. Seventh Conf. on Num. Wea. Prediction, June 1985, Montreal, Que., Canada.

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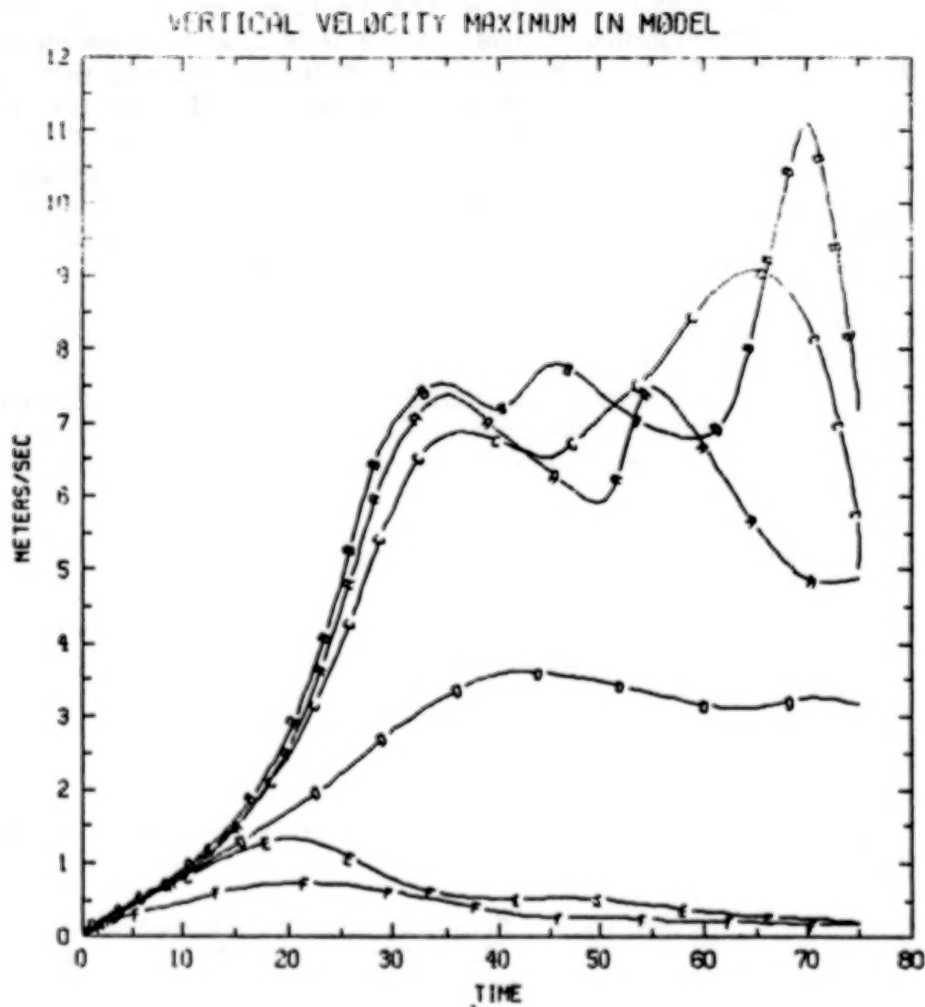


Figure 1. Cloud model maximum velocity for cases A through F. Case F corresponds to the right most position in the mesoscale model while case A is the left most or furthest to the west.

TITLE: Mesoscale Research Activities with the LAMPS Model

INVESTIGATOR: Michael W. Kalb
Universities Space Research Association
NASA/Marshall Space Flight Center, ED-43
Huntsville, AL 35812

ACCOMPLISHMENTS TO DATE:

- 1) Have achieved full implementation of the LAMPS mesoscale model on Atmospheric Sciences Division computer.
- 2) Derived balanced and real wind initial states for three case studies: March 6, April 24, April 26, 1982.
- 3) Performed numerical simulations for three separate studies:
 - a) Satellite moisture data impact study using VAS precipitable water as a constraint on model initial state moisture analyses.
 - b) Evaluation of mesoscale model precipitation simulation accuracy with and without convective parameterization.
 - c) Sensitivity of model precipitation to mesoscale detail of moisture and vertical motion in an initial state.

These last two studies will be discussed in the research review.

CURRENT ACTIVITIES:

- 1) Continuing convective/non-convective testing of model on simulations for case studies listed above.
- 2) Continuing moisture sensitivity studies for April 24 and 26.
- 3) Examining model statistical relationships between surface precipitation rates and vertical profile characteristics for rain water, vertical velocity and moist diabatic heating. Intent is to study possibilities for devising a scheme to provide a moist initialization for the LAMPS model based upon observed precipitation rates.

ACTIVITIES FOR FY-86:

- 1) Develop a moist model-initialization technique to enhance initial moisture fields in the LAMPS model.
- 2) Run for the several case studies mentioned above, a general mesoscale data sampling impact study for moisture and temperature. Study will be in the context of response of model simulations initialized with various amounts of detail in their initial states.
- 3) Begin study of impact of satellite sounding data characteristics on mesoscale numerical weather prediction. This is to be accomplished by deriving "satellite" soundings from control model simulated temperature and

moisture profiles, and then using those soundings to generate a new initial state and forecast to be compared to the control forecast.

4) Will implement a variational objective analysis for model initialization with satellite derived moisture.

5) Obtain new improved satellite soundings for March 6, 1982 using University of Wisconsin's simultaneous retrieval technique to continue study impact of satellite precipitable water constraint on mesoscale model precipitation simulations.

RECOMMENDATIONS FOR FUTURE RESEARCH:

1) Perform comparisons of LAMPS 1-D cumulus cloud model temperature and moisture tendencies with those obtained from the South Dakota University's 2-D cloud model.

2) Perform strict inter-model comparisons for specific case studies, e.g. LAMP versus MASS model for May 20, 1979.

PUBLICATIONS SINCE JUNE 1984:

Initialization of Mesoscale Model for April 10, 1979 Using Alternative Data Sources. NASA Contractor Report 3826, August 1984.

Sensitivity of a Mesoscale Model to Initial Specification of Relative Humidity, Liquid Water and Vertical Motion. With Donald J. Perkey. (To be presented at Numerical Weather Prediction Conference in June 1985.)

Simulations of Mesoscale Convective Response. With Richard T. McNider, Fred J. Kopp and Gregory S. Wilson. (To be presented at Numerical Weather Prediction Conference in June 1985.)

Results from a Limited Area Mesoscale Numerical Simulation for 10 April 1979. To appear in Monthly Weather Review in 1985.

TITLE: Cooperative VAS Program with NASA Marshall Space Flight Center

INVESTIGATOR: David D. Houghton
 Department of Meteorology
 University of Wisconsin
 1225 W. Dayton Street
 Madison, WI 53706
 (608) 262-0776

RESEARCH ACCOMPLISHMENTS:

Progress to make the Drexel/NCAR regional numerical model, LAMPS, on line for research was highlighted by the appointment of Scott Lindstrom with a full time commitment to implement and manage LAMPS for project work at the University of Wisconsin. He has already met with Dr. Perkey, Drexel, and Dr. Kalb, NASA, to gain the expertise needed to do this job. The current plan is to bring the model up on the NCAR CRAY. Using the computer facilities at NASA/Marshall is another option.

Advances in the research related to LAMPS await that model becoming available. In the interim research has been conducted with the Sub-Synoptic Scale Model (SSM) at the University of Wisconsin as discussed following.

FOCUS OF CURRENT RESEARCH ACTIVITIES:

1. Importance of mesoscale moisture information in the forecasting of weather events.

A test is being prepared with the March 6, 1982 VAS/AVE case study to be run on the SSM. Model intracomparison of three carefully designed simulations should isolate the role of mesoscale information in the initial conditions for both moisture and vertical motion.

Three simulations will be made for the period 1200Z 6 March to 0000Z 7 March starting with the regular synoptic time data of 1200Z. The distinction between the three cases arises from data manipulation at 1800Z midway through the forecast period:

- a) Control Case: no alterations at 1800Z
- b) Moisture Information Suppression: at 1800Z the model simulation field for water vapor, which by this time contains considerable mesoscale structure, is replaced by a smoothed version from which the mesoscale structure has been eliminated. No other variables are structure altered.
- c) Vertical Motion Information Suppression: at 1800Z the model is subjected to a "dead start" procedure which primarily imposes a "non divergent" constraint of the horizontal motion field suppressing vertical motion. The main effect is to eliminate the mesoscale component.

Comparison of results for the 1800Z to 0000Z time period will give the information desired.

2. Validation of precipitation forecasts.

Recognizing that precipitation forecasts are one of the most important products to be gained from regional numerical models, a study has been initiated to examine the performance of the SSM in this regard. The important problem of determining the verification data is also addressed.

In this study the 24 hour precipitation forecast of the SSM for July 20, 1981 is examined and compared with rain gauge data from all available points (including climatological and cooperative observing stations) and is compared with rainfall estimates from satellite imagery (the Schofield technique used at NESDIS). The NWS LFM operational precipitation forecast for the same period is also examined. It is hoped to learn about the options available for verification data as well as performance characteristics of the SSM.

3. Preparing data files for LAMPS simulations.

In anticipation of the availability of LAMPS, work continues to prepare appropriate initial data files for the 1982 VAS/AVE case studies, March 6, April 24, and April 26. Both conventional data sets and those including satellite information are being considered.

PLANS FOR FY-86:

The first two studies described above will be completed before FY-86. It is planned to continue work in the following areas:

1) Examine more case studies to further isolate the importance of mesoscale information for moisture and wind in the initial data specification on the forecasts of regional numerical models (both the LAMPS and SSM). This encompasses elements of the first two modeling research goals listed in the proposal document of March 1984 dealing with moisture and wind observations. Special attention will be given to satellite winds.

2) Conduct model intercomparison studies between the SSM and LAMPS focusing of the ability of each to utilize initial mesoscale information, to simulate moist convection and to forecast total rainfall amounts.

RECOMMENDATIONS FOR NEW RESEARCH:

1) Examine the relative importance of initial mesoscale data to model parameterization for regional numerical model performance.

2) Explore initialization techniques for the motion field that may be able to retain mesoscale vertical motion information to improve the first 3 hours of the forecast.

PUBLICATIONS SINCE JUNE 1984:

None (delays in LAMPS had a serious effect on research progress).

TITLE: The Assimilation of Satellite Soundings, Winds and Satellite Products in a Mesoscale Analysis/Forecast System

INVESTIGATORS: George R. Diak, (608) 263-5862
William L. Smith, (608) 263-4085
Space Science and Engineering Center
University of Wisconsin
1225 West Dayton Street
Madison, Wisconsin 53706

ACCOMPLISHMENTS IN FY-85:

Our investigations in FY-85 are centered on three case study days in 1982. Two of these, March 6 and April 24, were AVE/VAS days for which high spatial and temporal resolution RAOB and VAS data sets were available. The third investigation day, April 26, was a day of interesting severe weather. In the last part of FY-84 and early FY-85 we were able to demonstrate most importantly the complimentary nature of satellite soundings and winds in a forecast/analysis system. In our variational analysis scheme, cloud drift and water vapor winds enter into the height field as gradient information. The cloud drift winds especially, have the character of supplying information in cloudy areas where satellite soundings are not possible. In the April 26 experiments, analyses and forecasts using the combination satellite winds and soundings were superior to those using only soundings. Good consistency was shown between independent satellite forecasts from different initialization times run to the same verification time.

A significant accomplishment in FY-85 was expanding experiments on April 26 to include a quasi-continuous initialization inserting satellite soundings and winds from several different times into an analysis/forecast. Contrary to the first set of experiments on April 26, here forecast initialization fields were not independent, but contained satellite information from two data times. The guess field for a satellite update at 1730 GMT was a forecast from 1430 GMT analysis also containing satellite soundings and winds. The forecast produced from this multiple assimilation was good in both primary variables and precipitation. A normal mode initialization procedure recently implemented in our mesoscale model was instrumental in reducing spurious model oscillations in this experiment.

In FY-85 we have begun experiments to determine how to best utilize the information in VAS soundings for numerical analyses and forecasts. One possibility is that using the horizontal gradient information may alleviate some of the bias problems associated with the soundings. Toward this end we have run experiments on the March 6 case in which gradients of VAS heights were input to the analyses rather than absolute values. The analysis using this methodology for March 6 was superior to those using absolute values, with the corresponding forecast also somewhat better.

FOCUS OF CURRENT RESEARCH ACTIVITIES:

VAS gradient analyses for the case study day of April 24 have recently been completed. After evaluation of these analyses, we will be running forecasts from these analyses for comparison with those already made using VAS height analyses.

Work has begun on implementing an improved version of our meso-scale model on the SSEC computing facility and development of improved techniques for quasi-continuous asynoptic data assimilation is in progress.

PLANS FOR FY-86 AND RECOMMENDATIONS FOR NEW RESEARCH:

In FY-86 we need to assemble as much basic knowledge as possible on the assimilation of satellite soundings and winds. This will involve completing studies for the three case study days with various combinations of data input (soundings, soundings and winds, gradients, gradients and winds, etc.). With this information, we hope to be able to make a more general evaluation of the merits of various combinations. Separate experiments will also be run assimilating only VAS moisture information to attempt to delineate the role of moisture information in forecasts. We wish to begin work on a technique to assimilate VAS moisture gradient information using total column precipitable water from satellite as a variational constraint.

We have just begun a series of numerical forecast experiments to try to delineate the role of mesoscale moisture structure in the forecasting of precipitation. These experiments will involve various wavelength numerical smoothing of forecast-model generated moisture structures. Subsequent continuation of the forecasts with the smoothed moisture fields and comparisons with control forecasts should give insight into the importance of meso-scale moisture features.

PUBLICATIONS:

LeMarshall, J., G. Diak, W. L. Smith, G. Callan, and T. Stewart, 1985: Synoptic Scale Analysis and Forecasting Using VAS Soundings and Cloud and Water Vapor Drift Winds. Submitted to Mon. Wea. Rev.

Smith, W. L., G. S. Wade, W. P. Menzel, V. E. Suomi, R. J. Fox, C. S. Velden, and J. F. LeMarshall, 1984: Nowcasting — Advances with McIDAS III. Volume of reprints, Nowcasting 2 Symposium, Norikeping, Sweden, Sept. 3-7, 1984.

Smith, W. L. and G. A. Kelly, 1985: Use of Satellite Imagery and Soundings in Mesoscale Analysis and Forecasting. To be presented at Nowcasting 2A Symposium, Hawaii, August 6, 1985.

TITLE: Numerical Simulation of Convective Response to Mesoscale Forcing

INVESTIGATORS: Richard T. McNider
University of Alabama in Huntsville
Huntsville, AL 35899
(205) 895-6257

Fred J. Kopp
South Dakota School of Mines
Rapid City, SD 57701
(605) 394-2291

Michael W. Kalb
Universities Space Research Associates
Marshall Space Flight Center, AL 35812
(205) 453-5532

Gregory S. Wilson
Atmospheric Science Division
Marshall Space Flight Center, AL 35812
(205) 453-2518

SIGNIFICANT ACCOMPLISHMENTS FOR FY-85:

A two-dimensional mesoscale model has been used to initialize a two-dimensional cloud model with both mesoscale thermodynamic and dynamic information utilized in the initialization. The Mesoscale-cloud model linkage has been used to examine differential convective response due to mesoscale variations for the April 24, 1982, AVE-VAS Case IV. On this day both data analyses and mesoscale model simulations indicated strong variations in thermodynamic and dynamic structure across the panhandle of Texas where a moderately strong convective line formed. Using the cloud model, the current research has shown a preferred area for strong convection to occur due to concomitant mesoscale convergence and mesoscale destabilization of the atmosphere.

FOCUS OF CURRENT RESEARCH:

The above work has concentrated on transfer of mean mesoscale thermodynamic and dynamic structure to the cloud model with an imposed temperature perturbation to start the convection. A more consistent mechanism would be to scale the temperature perturbation to dry convective boundary layer scales such as the convective velocity scale, W_* , and the planetary boundary layer height, Z_i . These parameters are available from the mesoscale model; thus fine scale structure in the cloud model initial conditions can perhaps be initialized consistent with the mesoscale model boundary layer.

PLANS FOR FY-86:

A series of experiments will be made to evaluate the sensitivity of convective response in the cloud model to parameterization of initial

temperature perturbations. If the sensitivity proves significant, then a parameterization scheme will be developed to specify temperature perturbations from boundary layer scaling.

RECOMMENDATIONS FOR NEW RESEARCH:

Previous modeling studies of cloud response to imposed mesoscale forcing by South Dakota investigators have indicated that mesoscale convergence shifts the spectral energy of convection to longer wavelengths. This should be studied in more detail to evaluate what is causing the shift. Also observation and analysis methods for examining these characteristics under the SPACE field program should be developed.

PUBLICATIONS:

McNider, R. T., F. J. Kopp, M. W. Kalb, and G. S. Wilson, 1985: Simulation of Mesoscale Convective Response. Proceedings of Seventh Conference on Numerical Weather Prediction, AMS.

TITLE: A Summary of Research on Mesoscale Energetics of Severe Storm Environments

INVESTIGATOR: Henry E. Fuelberg
Department of Earth and Atmospheric Sciences
Saint Louis University
St. Louis, MO 63103
(314) 658-3121

SIGNIFICANT ACCOMPLISHMENTS:

This research was completed in early FY-85. Its goals were to better understand interactions between areas of intense convection and their surrounding mesoscale environments by using diagnostic budgets of kinetic (KE) and available potential energy (APE). Accomplishments during the six year funding period are summarized below.

Three cases of intense convection were examined in detail:

AVE IV — 24-25 April 1975, synoptic scale data at 3 to 6 hour intervals, contained two mesoscale convective complexes (MCCs). Analyses included total KE budgets and budgets of divergent and rotational components of KE.

AVE-SESAME I — 10-11 April 1979, synoptic and meso α -scale data (250 km spacing, 3 hour intervals), contained the Red River Valley tornado outbreak. Analyses included total KE budgets (separate synoptic and mesoscale versions), budgets for the divergent and rotational components, and the generation of APE by diabatic processes.

AVE-SESAME V — 20-21 May 1979, synoptic and meso β -scale data (75 km spacing, 1 1/2 to 3 hour intervals), contained a small MCC. Analyses include separate KE budgets for the synoptic and meso β -scales and a water vapor budget.

Major findings of these investigations are:

- 1) The synoptic scale storm environment contains energy conversions and transports that are comparable to those of mature midlatitude cyclones.
- 2) Energetics in the mesoscale storm environment are often an order of magnitude larger than those in an undisturbed region.
- 3) Mesoscale wind maxima form in the upper troposphere on the poleward sides of convective areas, whereas speeds decrease south of storm regions. For large areas of storms (i.e., MCCs), these changes are detectable with the standard radiosonde network; however, for smaller storm complexes, special data networks are required (e.g., AVE-SESAME). Nonetheless, the wind changes appear similar, no matter at what scale they occur.

4) Due to latent heat release, geopotential heights in the storm environment are observed to rise concurrent with an increase in the divergent wind component. Thus, north of the storms, there is strong generation of kinetic energy by cross-contour flow. This appears to be the primary mechanism by which the upper level jetlet is formed. Conversely, south of the storms, there is a destruction of kinetic energy by cross-contour flow.

5) Directly over storm areas, winds above ~350 mb decrease during convective formation, whereas they increase within the 550-350 mb layer. We have called this a "vertical wind couplet." The result is a major reduction in vertical wind shear.

6) These differential changes in speed (KE) arise because of particular combinations of source/sink terms in the budget equation. In particular, the dissipation term suggests that transfers of energy between resolvable and unresolvable scales of motion are an especially important process.

There are several important implications to the research. First, our knowledge of storm/environment interactions still is very incomplete. Thus, when possible, these mesoscale fluctuations should be detected, possibly by satellite sensors, so that they can be studied in greater detail and included in forecast considerations. Also, using mesoscale models, we should investigate the role of latent heat release in producing the observed variations. The goal of these efforts should be to successfully parameterize storm/environment interactions within mesoscale prediction models.

CURRENT ACTIVITIES:

None. The contract has been completed.

RECOMMENDATIONS FOR NEW RESEARCH:

MASS and LAMPS model output should be used to investigate mesoscale wind (KE) variations near areas of intense convection. Experiments involving moist and dry runs would elucidate causes for observed fluctuations, i.e., upper tropospheric maxima and minima, as well as vertical wind couplets. The 10-11 April (AVE-SESAME I) case is especially suited for study because the models have produced excellent results, and because comparative diagnostics already are available.

The primary thrust should be to explore the dynamics of the interactions. We do not wish to simply compare the energetics of model simulations with observed results. By emphasizing causes for the phenomena, we would insure that the models obtain the right answers for the right reasons. Energy analyses are proven aids in understanding large scale model processes, e.g., the NCAR GCM, and we believe they will be equally valuable for learning more about mesoscale features.

80851-28W

PUBLICATIONS SINCE JUNE 1984:

Fuelberg, H. E., and D. E. Buechler, 1985: Budgets of Divergent and Rotational Kinetic Energy During Two Periods of Intense Convection. Submitted to Mon. Wea. Rev.

Fuelberg, H. E., and M. F. Printy, 1984: A Kinetic Energy Analysis of the Meso β -Scale Severe Storm Environment. J. Atmos. Sci., Vol. 41, pp. 3212-3226.

Fuelberg, H. E., M. G. Ruminski, and D. O'C. Starr, 1985: Mesoscale Generation of Available Potential Energy in the Warm Sector of an Extratropical Cyclone. Mon. Wea. Rev., Vol. 113, in press.

Lin, Y. J., H. W. Chang, and H. E. Fuelberg, 1985: A Moisture Analysis of the Meso β -scale Thunderstorm Environment During AVE-SESAME V (20-21 May 1979). Submitted to Mon. Wea. Rev.

TITLE: Time Composite Sounding

INVESTIGATOR: Christopher Hayden
1225 West Dayton Street
Madison, Wisconsin 53706
(608) 264-5325

ACCOMPLISHMENTS:

In the time composite sounding mode, the VAS data is collected in a series of "images" of one spin each rather than in the "dwell sound" mode where single lines are repeatedly scanned. A drawback of the time composite method is temporal smearing of the data, but to compensate this there is also the chance that shifting cloud patterns will permit better spatial coverage. Time composite sounding was performed for a single case study, June 14, 1984. Four, ten minute single spin swaths were processed. The principal conclusion reached was that the time composite results were at least equivalent to the conventional dwell sounding results, despite the fact that compositing was done in a less than optimum way because of software limitations.

CURRENT RESEARCH:

There is a very low level effort underway at CIMSS to develop improved software for time compositing of the VAS measurements. An enormous amount of data has been collected in this mode which awaits processing.

PLANS FOR FY-86:

The time compositing software will be completed on a time available basis. We hope to do more through research in the form of additional case studies. We believe that time composite sounding is highly desirable because it will suit more users in terms of providing quasi-continuous sounding and imaging. There is a need to investigate the attributes of this mode prior to committing to an operational VAS sounding methodology.

REFERENCES:

The results of this research were presented at the Conference on Satellite Meteorology/Remote Sensing and Applications, June 25-29, 1984, Clearwater Beach, Florida.

TITLE: Investigations of Severe/Tornadic Thunderstorm Development and Evolution Based on Satellite and AVE/SESAME/VAS Data

INVESTIGATORS: Thomas H. Vonder Haar
Director, CIRA, Colorado State University
Ft. Collins, CO 80523
(303) 491-8566

James F. W. Purdom
Chief, NESDIS/RAMM Branch, CIRA Bldg.,
Colorado State University
Ft. Collins, CO 80523
(303) 491-8446.

SIGNIFICANT ACCOMPLISHMENTS TO DATE IN FY-85:

Continued development of cloud relative tracking for severe thunderstorm identification and beginning the development of mesoscale air mass characteristics based on VAS sounding data.

FOCUS OF CURRENT RESEARCH ACTIVITIES:

The development and evolution of deep convection and severe thunderstorms.

PLANS FOR FY-86:

- 1) Assimilate rapid-scan cases and analyze wind shear relative to severe storms.
- 2) In conjunction with No. 1 using VAS data, determine mesoscale air mass characteristics for the severe storm environment.

RECOMMENDATIONS FOR NEW RESEARCH:

Involvement with the SPACE Program.

PUBLICATIONS PREPARED SINCE JUNE 1984:

Purdom, J. F., T. H. Vonder Haar, J. K. Stewart and N. E. Leary, 1984: Diagnosing the Severe Thunderstorm Environment by Mesoscale Cloud Tracking - A New Approach and New Information. Conference on Satellite/Remote Sensing and Applications, Clearwater Beach, FL, Amer. Meteor. Soc., pp. 100-105.

Purdom, J. F. W., 1984: Use of Satellite Soundings and Imagery for Nowcasting and Very-Short-Range Forecasting. Preprints, Nowcasting II Symposium, Norrkoping, Sweden, European Space Agency, pp. 99-111.

Purdom, J. F. W.: Convective Scale Weather Analysis and Forecasting. Now in progress, Chapter for 25th Silver Anniversary Book on Meteorological Satellites.

I. Introduction

Scientific investigations were undertaken in three areas. Those areas were: (1) research of rapid scan satellite imagery to investigate the severe thunderstorm's local environment; (2) investigations of the April 10, 1979 AVE/SESAME case using rapid scan satellite imagery and AVE sounding data; and (3) investigations of VAS imagery for mesoscale applications. Each of the three above areas were investigated with the premise that they were part of a three year collaborative effort. The major emphasis during this first year study period has been in area No. 1.

II. Reading Satellite Research Rapid Scan Imagery to Investigate the Severe Thunderstorm Environment - Vertical Wind Shear and Storm Relative Flow

a. An important new technique for mesoscale cloud tracking.

Because of the tremendous number of observations that can be obtained with satellite data in mesoscale space and time domains, satellite cloud motion fields have great potential for studying the precursor severe storm environment and other mesoscale phenomena. While the potential of mesoscale cloud tracking has been demonstrated, considerable difficulty may be encountered when attempting to create mesoscale flow fields using rapid scan satellite imagery. This is especially true the more strongly sheared the environment in which the clouds to be tracked are developing.

In a highly sheared severe storm environment with strong low level flow, cumulus clouds move rapidly as they evolve over short time periods. Under such conditions, the top portion of a cumulus may be vertically growing while also moving in a direction that is different from its lower portion. The rapid movement and growth of the cumulus in a sheared environment can produce a confusing picture to the cloud trackers and make the determination of accurate cloud motions very difficult. With these thoughts in mind, a new and simple method for mesoscale cloud tracking was developed for the CSU IRIS system.

In the new method, a cloud whose motion is representative of the cloud field of interest is identified. That cloud is then tracked, and its motion is used to re-navigate the original sequence of images over the area of interest. When this re-registered image sequence is viewed in animation, the "representative cloud" is stationary as are other clouds like it. With the mean motion having been extracted from the cloud field, variations in motion between similar clouds as well as growth, decay and shear are readily detectable.

While the tracking of clouds in a cloud relative mode may seem the same in principal to that in an earth relative framework, it is not. There is a very basic and fundamental difference. For now instead of following a cloud from one point to another, the function of the cloud tracker has changed. The analyst is now monitoring cloud growth and asynchronous translation over a finite amount of time and assigning displacements to appropriate portions of that cloud - this is easy to do since the cloud is

basically standing still and we are observing its evolution. This same function is extremely difficult to do in earth relative coordinates where a cloud is seen to rapidly translate as it changes character.

b. Vertical wind shear and thunderstorm relative flow

It is well known that vertical wind shear plays an important role in determining the character of storms that evolve in a mesoscale environment. Furthermore, recent numerical cloud modeling studies have shown the importance of vertical wind shear in the formation of rotation in growing thunderstorms. However, a severe storm environment is one in which both the dynamic and thermodynamic characteristics of the atmosphere are changing on mesoscale space and time domains. Using our new method noted above, determination of vertical wind shear in regions of growing cumulus clouds using rapid scan satellite imagery is now feasible. We can study mesoscale variations in that parameter over large areas.

After thunderstorms have developed, animation of the imagery may be done relative to the thunderstorm. In such cases, the flows at different levels with respect to the storm may be inspected. Such a study was undertaken for the storm which produced the Wichita Falls tornado on April 10, 1979. A similar study was undertaken for the 28 March 1984 supercell storm that produced the devastating tornadoes in the Carolinas. In addition, we are testing this method using excellent CCOPE data sets where both ground and "air" truth are available. It is interesting to note how closely those relative flows compare to those for severe storms which travel to the right of the wind, and storm relative proximity soundings. Being able to diagnose storm relative flow has important implications for defining mesoscale regions that are favorable for the production of rotating storms and severe weather.

III. Investigations fo the 10 April 1979 Tornado Outbreak - The role of pre-existing low level cloud cover in the warm sector

Earlier work using satellite imagery has shown the strong effect early morning cloud cover may have on afternoon thunderstorm development. Our work on the April 10, 1979 tornado outbreak shows that early cloud cover can also influence the development of intense convection under conditions of strong synoptic scale forcing. On April 10, a mesoscale frontal boundary helped focus tornado activity in the Red River Valley area of Texas and Oklahoma. The most probable cause of that meso-front was differential heating due to cloud cover to its east versus a clear area to its west. The mechanism which led to the development of the meso-front, and subsequent focusing of tornadic activity, also played an important role in the development of instability in the warm sector. As the mesoscale frontal boundary moved eastward, mostly clear skies developed in the warm sector between the boundary and the stratiform overcast to its east. During that period Abilene, Texas became clear while Stephenville, Texas maintained its cloud cover. An analysis of surface static energy pointed to strong potential instability at both Abilene and Stephenville. However, time series of horizontal cross sections from mesoscale rawinsonde data from NASA's AVE SESAME experiment show a marked decrease in the amount of negative buoyant energy at Abilene and only a slight decrease at Stephenville: these changes are related to changes in cloud cover. Low level air, similar

in character to that near Abilene fed the tornadic storm system, allowing intense thunderstorms to develop.

Thus, we see that the effect of early morning cloud cover can be complicated indeed. It can act to set up a baroclinic zone (or reinforce an existing one) through differential heating. At the same time, it can affect the local destabilization of an airmass: (1) if skies clear too quickly, moisture may be mixed to great depths making the region unsuitable for supporting strong moist convection; (b) if the area remains cloudy, thunderstorms moving into the region might dissipate or weaken considerably due to the negatively buoyant low level air; (c) if the area clears an hour or two prior to thunderstorms moving into it, sufficient heating and mixing at low levels may have occurred, priming the local air mass to support explosive convection. Use of VAS sounding channel data should aid in the assessment of the convective potential of such situations for mesoscale forecasting.

IV. VAS Imagery for Mesoscale Applications

Work is currently underway which combines various channels of VAS data in image format to try and detect the development mesoscale structure in the atmosphere. In that work features such as vorticity maxima, jet streaks, thunderstorm complexes, etc. are being studied in time lapse in a "system" relative mode similar to that discussed previously. Results look very promising for detecting developing baroclinic regions as well as isolating mesoscale regions of stronger vertical forcing.

TITLE: Detection of Rotating Thunderstorms Using Satellite Imagery

INVESTIGATORS: Prof. C. E. Anderson
Dr. Robert Schlesinger
Dept. of Meteorology
University of Wisconsin-Madison
(608) 262-2828

SIGNIFICANT ACCOMPLISHMENTS TO DATE IN FY-85:

Performed research on the following tornadic storms:

Date of Storm	Place	Deaths
1. March 28, 1984	North and South Carolina	67
2. April 27, 1984	Wisconsin	3
3. June 8, 1984	Wisconsin	9

In the case of the Carolina tornadoes, we prepared visible and IR GOES imagery covering the period 2000 Z when the storm entered South Carolina from Georgia until it exited North Carolina at 0200 Z into Virginia. The GOES IR imagery clearly demonstrated that this storm was imbedded in a continuously propagating mesolow with a well defined cold dome. The ground damage track paralleled exactly with the cold dome throughout the storm's life across the Carolinas. There were no AVHRR data during the period to allow us to inspect the cloud top for warm temperature anomalies. The Carolina storm did exhibit rightward deviating outflow which was oriented about 60 degrees to the 300 mb streamlines. Even more spectacular was cirrus outflow from several separate thunderstorm complexes along the Carolina coasts. These outflows had almost 90 degree rightward deviation to the streamlines at their height levels. These more isolated storms developed earlier but in the same meteorological regime as did the main Carolina storm and thus could have been used as an early warning that tornadic storm development had a strong likelihood over the Carolinas that day. One of these isolated thunderstorms produced a tornado at Tabor City, N.C.

The tornadoes of April 27, 1984 were part of a tornado producing cold front which stretched from Oklahoma to Minnesota. As the front moved eastward it touched off numerous tornadoes in eastern Wisconsin. These were mainly short lived storms although considerable property damage occurred and 3 deaths were attributed to the tornadoes. We prepared GOES imagery for this date and it was strikingly clear that all along the North-South oriented squall line, the individual thunderstorms had cirrus plumes which had remarkable right deviation to the upper air flow. Unlike the Carolina long track supercell cell-mesolow system, these storms were isolated individual thunderstorms which touched off at least 16 tornadoes in eastern Wisconsin stretching from the Milwaukee area on the south to Vilas County in the north.

The monster tornado of June 8, 1984 which leveled 90 percent of the village of Barneveld, Wisconsin and killed 9 persons was the most violent

tornado in the U.S. in 1984. It was rated as F-5 by the University of Chicago field inspection team. Like the Carolina storm, it was produced from a continuously propagating mesolow which had a track of nearly 200 km. The mesolow itself seemed to be rotating and in the process produced spiral arms which in turn were the sites for the tornadoes. The major attention of our research has been focussed on this particular storm. There is also evidence of a very powerful right deviation of upper level cirrus outflow which is consistent with our previous observations.

FOCUS OF CURRENT RESEARCH ACTIVITIES:

The research on the June 8, 1984 storm is concentrated in four main areas: Goes satellite imagery, WSR-57 radar echoes, reconstructing the surface weather from weather service station records, and a microbarograph network located in Madison. We have been able to digitize the Neenah WSR-57 radar film and display it on McIDAS. This enables us to study in combination the radar data, the satellite data, and the debris fallout pattern in our efforts to seek a scientific explanation of the storm circulation and evolution in time which will be consistent with our factual data.

PLANS FOR FY-86:

We shall continue to search for hypotheses concerning the explanation of the strong correlation between rotating thunderstorms and strong right-deviating cirrus-level outflow. We plan to pursue some theoretical approaches suggested by Dr. William Raymond and Prof. Kuo which involve eigenvalue-eigenvector solutions for low wave number vortex flows. These latter studies were directed toward the explanation of hurricane spiral bands in the lower-level convergence region but the ideas should be applicable to the upper-level divergence region of the rotating thunderstorm.

We plan to continue to refine our data sets for the three 1984 tornado events discussed earlier in order to be able to diagnostically test whatever working hypothesis emerges from the theoretical studies.

RECOMMENDATION FOR NEW RESEARCH:

We would like to see a concerted effort made to have 3 minute GOES satellite imagery, multiple Doppler storm coverage, and AVHRR imagery for a long lived tornadic storm exemplified by the Carolina storm of March 28, 1984 or the Barneveld storm of June 8, 1984. In each of these, there were no such data. Thus, the task of reconstructing the storm dynamics and circulation for long lived, powerful (F3, F4, F5) tornadic storms is very difficult because of the paucity of relevant data.

PUBLICATIONS PREPARED SINCE JUNE 1984: (Prepared for presentation at the 14th Conference on Severe Local Storms).

Anderson, C. E.: The Fallout Pattern for Debris from the Barneveld, WI Tornado: An F-5 Storm.

Anderson, C.E.: The Barneveld Tornado: A New Type of Tornadic Storm.

TITLE: Statistical Analysis and Use of VAS Radiance Data

INVESTIGATOR: Henry E. Fuelberg
Department of Earth and Atmospheric Sciences
Saint Louis University
St. Louis, MO 63103
(314) 658-3121

SIGNIFICANT ACCOMPLISHMENTS TO DATE IN FY-85:

Our goals are to describe the information content of VAS radiance data, especially the $6.7 \mu\text{m}$ water vapor channel, to better interpret the atmosphere's water vapor structure from $6.7 \mu\text{m}$ imagery, and to investigate new analysis and forecasting techniques utilizing retrieved VAS soundings. We have made major progress toward these goals during FY-85.

1) We are investigating $6.7 \mu\text{m}$ imagery on 6-7 March 1982, a day when special mesoscale ground truth data were collected during the 1982 AVE/VAS Field Experiment. A dark (dry) image "streak" having mesoscale details was located over the special data region, and it provides the major focus of the case study. Mesoscale radiosonde-derived humidity data are found to verify fine scale features of the image that are not evident from the standard National Weather Service network. Thus, VAS imagery is a reliable detector of mesoscale moisture structure during this case.

To investigate causes for the image streak, we are calculating water vapor budgets. Several previous studies have emphasized the role of jet stream related subsidence in producing dry tongues. Subsidence is found to be a factor in the current case as well; however, patterns of descent are not related to the jet streak according to traditional conceptual models. Thus, it appears that more research into jet stream dynamics is needed in order to better interpret $6.7 \mu\text{m}$ imagery. Besides the effect of vertical motion, horizontal advection also plays a major role in producing the drying that appears as the image streak.

2) Retrieved soundings for 6-7 March 1982 are being investigated using statistical structure and correlation function analyses. Profiles from a physical procedure (Smith, University of Wisconsin) are compared with those using a regression technique (Lee et al., NASA/Goddard) and with ground truth radiosonde data. For temperature, gradients from the two retrieval schemes are similar to each other but considerably weaker than those from the radiosondes. In the case of humidity, gradients from the physical retrievals are more comparable to those from the sondes; however, the regression-derived data show few horizontal details. Temporal variability also is being assessed.

3) Several investigations have documented VAS's ability to detect small scale variations in temperature and humidity that often precede severe storm outbreaks. We are investigating the third requirement for thunderstorm formation — upward vertical motion. With VAS soundings for 21 July 1982 as input, vertical motions have been calculated using the

adiabatic, vorticity, and quasi-geostrophic omega equation techniques. Results from the omega equation are found to be best during the period of study. Specifically, patterns relate well to an upper air trough and to the convective outbreak. Vertical motions from the vorticity method are somewhat less favorable because of the presence of a time derivative term. Adiabatic motions are virtually useless because the time derivative is dominated by questionable temperature variations that cause component results to be much greater than those from the horizontal advection term. To further understand the pre-storm environment, stability and precipitable water were calculated. Temporal variations in the Lifted Index are due mostly to surface fluctuations. Thus, upper air data are not that important during the period. Changes in precipitable water do not seem related to the convective outbreak.

4) We are just beginning to consider the information content analysis of VAS radiances and retrievals on 6-7 March 1982. Thus far, first guess (LFM) profiles have been compared to the final output soundings. Results show that VAS adds a great deal of temporal and spatial detail. The amount of this detail that is meteorologically significant is being assessed through Task 2 above. The next step will be to compare the information content of the channel radiances to that of the retrieved soundings.

FOCUS OF CURRENT RESEARCH ACTIVITIES:

Having completed water vapor budget analyses on 6-7 March 1982, we are beginning a new phase of research involving radiation considerations. Specifically, NOAA/NESDIS has provided a radiative transfer model to which we will input radiosonde-derived soundings. The purpose is to relate temperature and humidity profiles to the detected radiation. Also, the information content of VAS radiances is being explored in detail through structure and correlation function analyses. Finally, follow on research into satellite-derived vertical motion is being considered. It is thought that Smith's recent algorithm modifications that reduce fictitious diurnal temperature variations will lead to improved vertical motions. Thus, a new set of retrievals may be utilized.

PLANS FOR FY-86:

We will complete many of the above mentioned tasks. Highest priority will be given to the information content analysis of VAS radiances.

RECOMMENDATIONS FOR NEW RESEARCH:

In order to use water vapor images as diagnostic aids, we must better understand causes for vertical motion, especially factors that produce mesoscale patterns. Further research into jet streak-induced vertical motions is especially needed. The dynamics of simple situations already has been explored; however, the atmosphere seldom fits these simple models. The case of 6-7 March 1982 would be an interesting case for study since jet structure is more complex.

PUBLICATIONS SINCE JUNE 1984:

Fuelberg, H. E., and T. W. Funk, 1985: Diagnosing Vertical Motions from VAS Retrievals During a Convective Outbreak. Preprints Fourteenth Conf. Severe Local Storms, Indianapolis, Amer. Meteor. Soc., in press.

Fuelberg, H. E., and P. J. Meyer, 1984: A Analysis of the AVE-SESAME I Period Using Statistical Structure and Corelation Functions. Mon. Wea. Rev., Vol. 11, pp. 1562-1576.

Fuelberg, H. E., and P. J. Meyer, 1985: An Analysis of Mesoscale VAS Retrievals Using Statistical Structure Functions. Conditionally accepted for J. Clim. Appl. Meteor.

Funk, T. W., and H. E. Fuelberg, 1985: Diagnosis of Vertical Motions from VAS retrievals During a Convective Outbreak. NASA CR in press.

Meyer, P. J., and H. E. Fuelberg, 1985: A Comparison of VAS- and Rawinsonde-Derived Soundings Utilizing Statistical Structure Function Analyses. NASA CR in press.

New Address:

H. E. Fuelberg
Department of Meteorology
Florida State University
Tallahassee, FL 32306

TITLE: Improved Satellite Retrievals and Mesoscale Moisture Variability

INVESTIGATOR: Gary J. Jedlovec
USRA Research Associate
Marshall Space Flight Center, ED-43
Huntsville, AL 35812

SIGNIFICANT ACCOMPLISHMENTS:

The investigations over the past year have led to the finalization of results from the study of mesoscale atmospheric parameters derived from the VISSR Atmospheric Sounder (VAS). Soundings from several retrieval techniques for the 6-7 March 1982 special observation period were evaluated for mesoscale accuracy. Specific results and comparisons between data from a regression and two physical retrieval schemes are forthcoming in the Journal of Atmospheric and Oceanic Technology (JTech) this year. A generalization of these results is outlined below.

- 1) Large temperature and moisture biases existed in the VAS derived profiles, particularly in layers near inversions. Standard errors ranged from 1 to 3°C and 3 to 6°C for temperature and dewpoint, respectively.
- 2) Parameters derived from VAS soundings (geopotential height, thickness, and precipitable water) often reflected the temperature and moisture profile biases.
- 3) VAS derived mesoscale gradients were often weaker than those from corresponding rawinsonde data.
- 4) Little improvement was made in defining the vertical structure of the atmosphere over the first guess information. VAS soundings were able to improve on the horizontal structure due to the high spatial resolution of the radiance data.

In the spring of 1984, the Advanced Satellite Products Project (ASPP) group at the University of Wisconsin began using a new retrieval technique (Smith and Woolf, 1984) for its operational support of the VAS activities of NOAA. To demonstrate the improvement in this technique over previous operational algorithms, soundings were produced using this new "simultaneous" retrieval technique for the 6-7 March 1982 case study. Like the previous operational technique (Smith, 1983), this scheme is a physical inversion scheme but solves for the temperature and moisture profiles at the same time using a matrix technique. An evaluation of soundings from this method has resulted in the following conclusions.

- 1) Although some reduction in low level temperature biases occur, similar bias patterns existed as with the previous algorithms.
- 2) Large moisture biases produced by the earlier operational scheme were substantially reduced with the new "simultaneous" method.
- 3) Slightly better resolution of the low level temperature inversion and horizontal moisture structure was evident.

This latter point is exemplified by the accompanying figure which shows grid mean profiles of temperature and dewpoint at 1730 GMT.

CURRENT AND FUTURE ACTIVITIES:

In addition to the high quality VAS soundings produced by the simultaneous retrieval method, it also offers versatility in combining radiance measurements from a variety of sources. Smith and Woolf (1984) have showed that the method is useful in combining geostationary and polar orbiting sounder data to produce reliable soundings in clear and cloudy regions. Additionally, Smith et al., (1985) have shown that quantitative high resolution precipitable water measurements can be obtained via the simultaneous from the VAS moisture imagery. The variability of these values at small scales (<100 km) seems quite high but the accuracy of these precipitable water measurements from VAS imagery remain unknown.

The Multispectral Atmospheric Mapping Sensor (MAMS) with its very high resolution measurement capabilities is able to detect thermal emission from two water vapor absorption bands (6.7 and 12.7 m) and in the infrared window at 11.2 m. It is the goal of current and future research efforts to use these high resolution moisture measurements from MAMS (and supporting VAS and/or HIS measurements) to make precipitable water calculations with a horizontal resolution of less than 5 km. The simultaneous retrieval method will be an integral part in deriving these values.

PUBLICATIONS SINCE JUNE 1984:

An Evaluation and Comparison of Vertical Profile Data from the VISSR Atmospheric Sounder (VAS). Accepted for publication in JTech, 1985.

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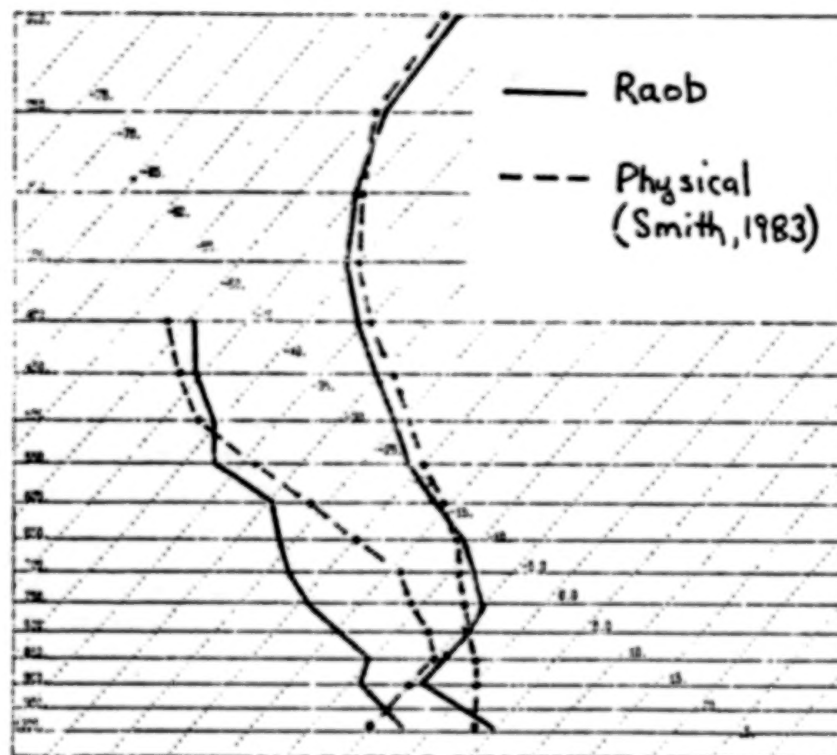
Smith, W. L., 1983: The Retrieval of Atmospheric Profiles from VAS Geostationary Radiance Observations. J. Atmos. Sci., Vol. 40, pp. 2025-2035.

Smith, W. L., and H. M. Woolf, 1984: Improved Vertical Soundings from an Amalgamation of Polar and Geostationary Radiance Observations. Preprints Conference on Satellite Meteorology/Remote Sensing and Applications, AMS, Boston.

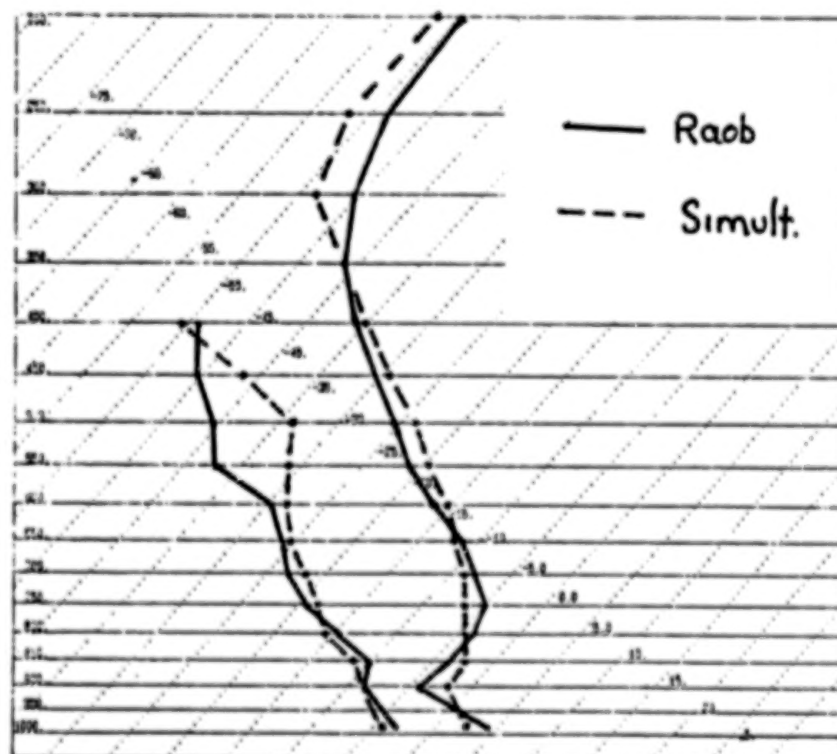
Smith, W. L., G. S. Wade, and H. M. Woolf, 1985: Combined Atmospheric Sounding/Cloud Imagery — A New Forecast Tool. BAMS, Vol. 66, pp. 138-141.

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FIELD EXPERIMENTS AND SUPPORTING DATA ANALYSIS SYSTEMS

TITLE: Studies of Humid Continental Haze During SPACE

INVESTIGATORS: David A. Bowdle
USRA Visiting Scientist
Marshall Space Flight Center, AL 35812
(205) 453-1325 or FTS 872-1325

William A. Greene
Atmospheric Sciences Division, ED43
Marshall Space Flight Center, AL 35812
(205) 453-1557 or FTS 872-1557

SIGNIFICANT ACCOMPLISHMENTS TO DATE IN FY-85:

1) Developed concept for solar radiometer network to provide supporting data during the Satellite Precipitation and Cloud Experiment (SPACE). Each of the 9 prime and 10 supplementary SPACE ground sites will be equipped with an upward pointing global solar pyranometer. About half of the sites will also be equipped with an upward pointing diffuse (shade ring) solar pyranometers, and a downward pointing global albedo pyranometer. These radiometers will be used to monitor the spatial and temporal variability of solar insolation and haze optical depth. The insolation data will ultimately be input to numerical models of the pre-storm and near-storm boundary layer. The optical depth data will be compared with simultaneous measurements from airborne and satellite-based passive visible radiometers and airborne lidars.

2) Located a major stockpile of solar radiometers from the defunct National Solar Data Network, under the management of the Vitro Corporation. Received written confirmation of Vitro's intent to deliver 50 Eppley Precision Spectral Pyranometers and 3 Eppley shade ring pyranometers to Marshall Space Flight Center.

3) Acquired 2 Eppley pyranometers, an Eppley pyrhelimeter, and a California Measurements absolute cavity radiometer within Marshall Space Flight Center.

FOCUS OF CURRENT RESEARCH ACTIVITIES:

1) Locate additional pyranometers and shade rings to complete the network. Design and fabricate the remaining shade rings.

2) Determine the sensitivity of numerical models of the pre-storm and near-storm boundary layer to infrared radiative heat fluxes. If warranted, locate and acquire enough infrared pyranometers (Pyrgeometers) to equip three to five SPACE sites with a pair of upward/downward pointing pyrgeometers for complete radiative energy budget studies.

3) Receive, refurbish, and calibrate the radiometers.

PLANS FOR FY-86:

Participate in the 1986 SPACE program. Perform pre- and post-SPACE radiometer intercomparison studies. Provide quick-look data sets as requested.

81821-080

RECOMMENDATIONS FOR NEW RESEARCH:

Analyze radiometer network data and compare with supporting data.
Provide quality-controlled data sets as requested.

PUBLICATIONS PREPARED SINCE JUNE 1984:

None at this time.

TITLE: Preliminary Planning for the Satellite Precipitation and Cloud Experiment (SPACE) Field Program

INVESTIGATORS: Steven F. Williams
Richard T. McNider
Johnson Environmental and Energy Center
The University of Alabama in Huntsville
Huntsville, Alabama 35899
(205) 895-6257

SIGNIFICANT ACCOMPLISHMENTS FOR FY-85:

Preliminary planning has been performed to support NASA/MSFC in the coordination of the field experiment to be conducted in Central Tennessee and Northern Alabama, and Mississippi during the Spring/Summer of 1986. The goal of SPACE is to investigate mesoscale cloud/precipitation systems and development of associated satellite remote sensing technology. The field program will incorporate remote sensing observations from aircraft, satellite imagery, radar observations, ground based lightning measurements, rawinsonde observations, and various surface meteorological observations. The coordination of existing and special observation networks will provide a data base for analysis of precipitation events and provide ground truth comparisons for remote sensing capabilities.

Existing surface-based observational networks include National Weather Service Meso/Alpha Scale Rawinsonde, radar, and surface measurements. The Tennessee Valley Authority automated and manual precipitation recording stations, and NASA/MSFC lightning measurement stations. Special observational features to be implemented include a meso/beta scale rawinsonde network, a special surface observational network within the rawinsonde network, and the installation of a RADAP II/ICRAD data processing unit on the NWS radar at Nashville, TN. Initial coordination of these observational requirements to accomplish the goals of SPACE have been performed.

FOCUS OF CURRENT RESEARCH:

Current efforts are underway to design and locate the special rawinsonde and surface networks. The rawinsonde networks will include nine (9) stations at a spacing of approximately 100 km. Observations will be taken on three (3) hour intervals over 15 to 20 operational days. Special observations such as 1½ hour launches and inclusion of observations from a tenth station will be performed during times of optimum storm development. Work is underway to obtain the necessary expendables and equipment for this network.

Space within the rawinsonde network will be eighteen surface stations to measure wind speed, wind direction, temperature, solar radiation, and precipitation. These stations will be comprised of NCAR's PAM II mesonet stations, and NASA/MSFC special stations. Current efforts are underway to locate additional sensors and data acquisition systems for the NASA stations, and interface solar radiation measurements into the PAM II stations.

A preliminary scouting trip to find suitable locations for both the special rawinsonde and surface networks will be performed shortly. Work will continue to coordinate all field experiment activities with participating groups and agencies involved in the program.

PLANS FOR FY-86:

The final development and operation of the field experiment will be performed. These plans include calibration of all equipment to be utilized, the training of equipment operators and technicians, procurement of all necessary supplies and equipment, deployment of all special observing stations, and coordination of all experiment operations. A field operational plan will be formulated and finalized. Following experiment completion, initial data processing and management will be performed.

TITLE: Atmospheric Modeling and Sensor Simulation (AMASS) Study

INVESTIGATOR: Karen G. Parker
New Technology, Inc.
4811 Bradford Blvd.
Huntsville, AL 35801

(205) 453-2570

SIGNIFICANT ACCOMPLISHMENTS IN FY-84:

1) A 4800 baud synchronous communications link was established between the Perkin-Elmer (P-E) 3250 AMASS system and the Cyber 205 located at GSFC.

2) An extensive study of off-the-shelf array processors offering standard interface to the Perkin-Elmer was conducted to determine which would meet computational requirements of the division. A Floating Point Systems AP-120B was borrowed from another MSFC laboratory for evaluation. It was determined that available array processors did not offer significantly more capabilities than the borrowed unit, although at least three other vendors indicated that standard Perkin-Elmer interfaces would be marketed in the future. Therefore, the recommendation was made to continue to utilize the 120B and to keep monitoring the AP market.

3) Hardware necessary to support requirements of the ASD as well as to enhance system performance was specified and procured. The original AMASS configuration is shown in Figure 1 and Figure 2 depicts the current system. Note that the dotted lines specify items in the procurement cycle at the current time.

4) Filters were implemented on the Harris/McIDAS system including two-dimensional lowpass, gradient, Laplacian, and bicubic interpolation routines.

CURRENT FOCUS OF RESEARCH:

1) Implement NEXRAD software on the Perkin-Elmer 3250 system.

2) Upgrade array processor software to match requirements of the new operating system (OS/32 MT 7.2.1).

3) Accomplish installation and checkout of Multiprocessor System (MPS) upgrade on the P-E. This modification should result in overall performance enhancement through the addition of an auxiliary processor unit.

FUTURE RESEARCH:

1) Preparation for connection to MSFC Class 6 system.

2) Evaluate impact of upgrading Harris/McIDAS to IBM system.

3) Determine means of improving existing image processing capabilities.

4) Investigate requirements of MAMS and Lightning Display packages.

PUBLICATIONS:

Parker, et al.: Interactive Information Processing for NASA's Mesoscale Analysis and Space Sensor Program. Proceedings of the International Conference on Interactive Information and Processing Systems for Meteorology, Oceanography and Hydrology, January 1985, Los Angeles, CA.

Final Report (Contract NAS8-35189): Atmospheric Modeling and Sensor Simulation (AMASS) Study. October 1984.

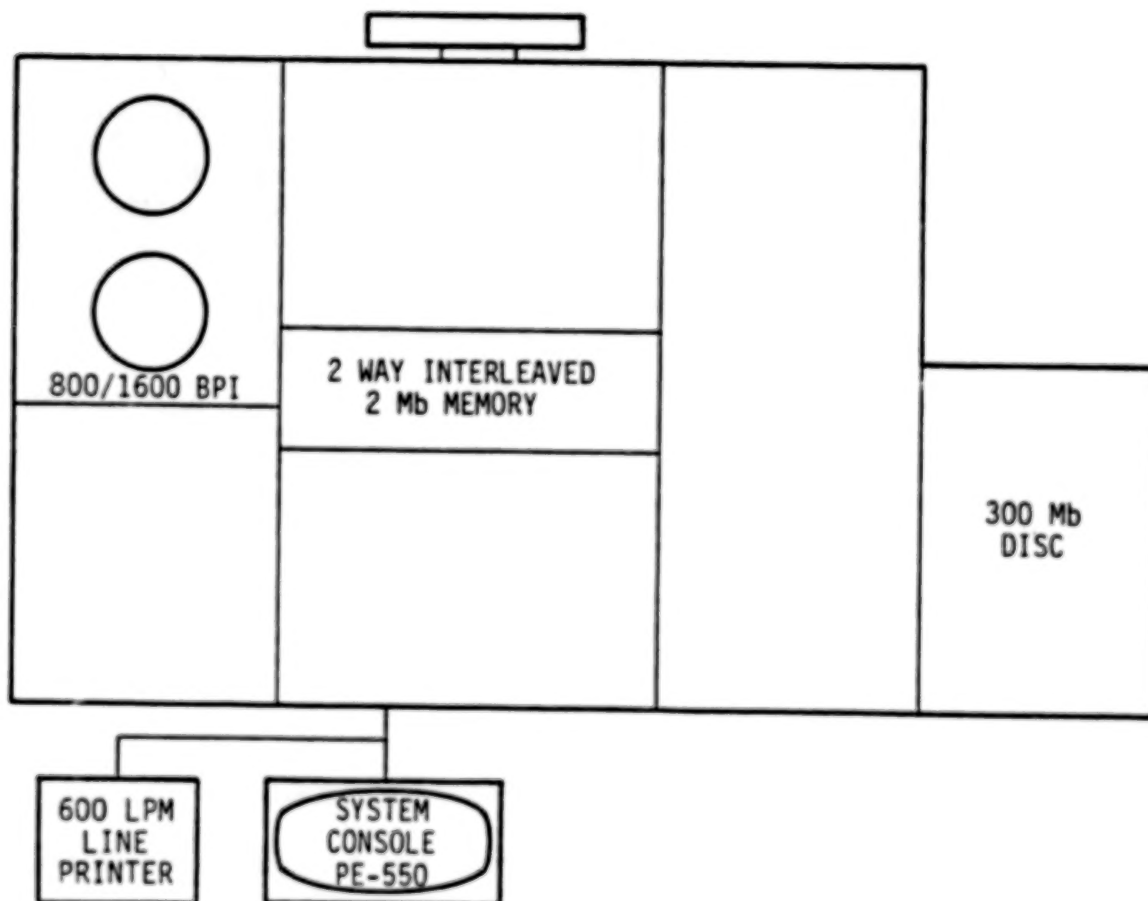


Figure 1. Original AMASS configuration.

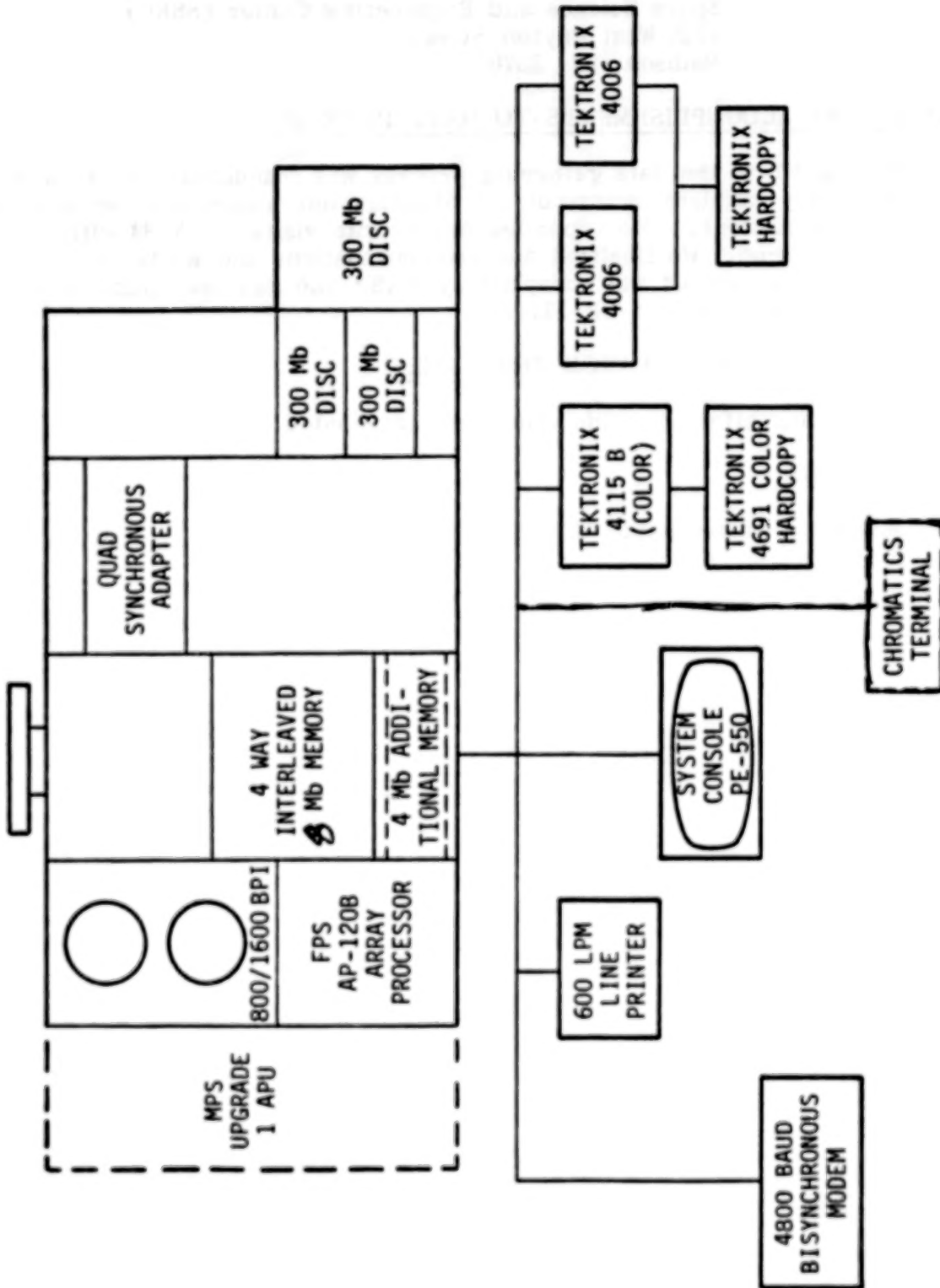


Figure 2. Current AMAS hardware configuration.

TITLE: The Meteorological Interactive Data Display System

INVESTIGATORS: Verner E. Suomi, (608) 262-6172
J. T. Young, (608) 262-6314
Space Science and Engineering Center (SSEC)
1225 West Dayton Street
Madison, WI 53706

SIGNIFICANT ACCOMPLISHMENTS TO DATE IN FY-85:

During FY-85 the data gathering process was completed. This gave us a reasonably complete picture of the Shuttle's operational weather support units and requirements. We expanded on the site visits of FY-84 with telephone follow-up. We finalized our recommendations and wrote the final report. The final report was accepted by NASA and has been published as NASA Contractor Report CR-171418.

FOCUS OF CURRENT RESEARCH ACTIVITIES:

No further efforts on this study are anticipated.

PUBLICATIONS:

NASA Contractor Report CR-171418.

TITLE: A Design Study for a Three-Dimensional Display Computer Terminal for Meteorological Information

INVESTIGATORS: Verner E. Suomi, (608) 262-6172
Robert J. Krauss, (608) 262-9523
Bill Hibbard, (608) 263-4427
J. T. Young, (608) 262-6314
Space Science and Engineering Center
1225 West Dayton Street
Madison, WI 53706

SIGNIFICANT ACCOMPLISHMENTS TO DATE IN FY-85:

The software developed on this project in FY-84 was put into final form and documented for McIDAS user access. The various users have been asked to utilize the techniques and to provide feedback to the developers. We have received limited feedback to date, but nearly all has been helpful and generally favorable. The stereo display has been used by most of the operational users of McIDAS or its progenies. Specifically, the National Hurricane Center, the National Severe Storm Forecast Center, the National Meteorological Center, and the Cape Canaveral Forecast Facility have all made use of the 4-D display techniques to help evaluate meteorological situations on various occasions.

In January 1985, we introduced the 4-D display at the AMS Conference in Los Angeles, CA. We set up our 4-D workstation in a booth in the exhibit hall and gave demonstrations of the polarized display and software operating remotely off the McIDAS in Wisconsin. The demonstrations were very well received and from our not impartial point of view, the hit of the conference.

FOCUS OF CURRENT RESEARCH ACTIVITIES:

Funds for this work were exhausted in November 1984 and consequently the work is on hold awaiting additional funding.

PLANS FOR FY-86:

In the near future, we plan to focus on the development of additional software to create realistic real-time weather displays and to integrate data from various 4-D sources into the data bases. The VAS retrieval products will provide finer time steps to the display of trajectories, and moist. Volumetric scan radar imagery will be integrated with the satellite displays and combined with scalar surfaces, flow fields, radar echoes and clouds into a single display.

The display hardware will be enhanced by the addition of large screen video displays for the polarized presentation. This will add to the realism of the presentation by filling most of the user's field of view and this will impart the feeling of being "in the weather."

PUBLICATIONS:

Hibbard, W., Robert J. Krauss, J. T. Young: 3-D Weather Displays Using McIDAS. Preprint of the AMS Conference on Interactive Processing, Los Angeles, CA, January 7-11, 1985.

TITLE: Interactive Information Processing for NASA's Mesoscale Analysis and Space Sensor Program

INVESTIGATORS: Karen G. Parker
New Technology, Inc.

Laura MacLean, Norman Reavis, and Gregory Wilson
NASA/Marshall Space Flight Center

John S. Hickey, Michael Dickerson, and Shogo Karitani
Atsuko Computing International

David Keller
Universities Space Research Association

Atmospheric Sciences Division/ED44
Marshall Space Flight Center, AL 35812

1. PROGRAM OVERVIEW AND DATA PROCESSING REQUIREMENTS

The Atmospheric Sciences Division (ASD) of the Systems Dynamics Laboratory at NASA's Marshall Space Flight Center (MSFC) is currently involved in interactive information processing for the Mesoscale Analysis and Space Sensor (MASS) program. Specifically, the ASD is engaged in the development and implementation of new space-borne remote sensing technology to observe and measure mesoscale atmospheric processes. These space measurements and conventional observational data are being processed together to gain an improved understanding of the mesoscale structure and the dynamical evolution of the atmosphere relative to cloud development and precipitation processes. Figure 1-1 provides an overview of this ASD research and development effort.

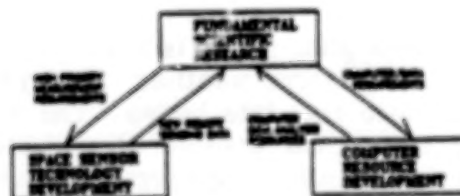


Figure 1-1. ASD Research and Development Activities.

To satisfy its vast data processing requirements, the ASD has developed a Research Computer System consisting of three primary computer systems (as shown in Figure 1-2) which provides over 20 scientists with a wide range of capabilities for processing and displaying large volumes of remote sensing data. Each of the computers performs a specific function according to its unique capabilities:

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a) Hewlett-Packard (HP-1000F) is utilized for management of large volumes of conventional and satellite derived meteorological data, data analysis and graphical display, and general-purpose computing.

b) Harris/6 Man Computer Interactive Data Access System (McIDAS) is connected to the IBM McIDAS system at the University of Wisconsin thus allowing for convenient access and analysis of real-time data, satellite and conventional research data bases and providing for graphical display/animation of space image data.

c) Perkin-Elmer (P-E 3250) is utilized for numerical modeling and large number crunching tasks and has direct Remote Job Entry (RJE) access to a NASA Class VI computer (Cyber 205 located at Goddard Space Flight Center).

Scientists may access any of the three minicomputers from the convenience of their office or remote location using an Apple III microcomputer workstation.

The primary focus of this paper is to convey a description of the overall architecture, software, data management and display capabilities of the ASD Research Computer System in terms of the manner in which it provides the scientists with a very effective interactive research tool for the Mesoscale Analysis and Space Sensor program information processing.

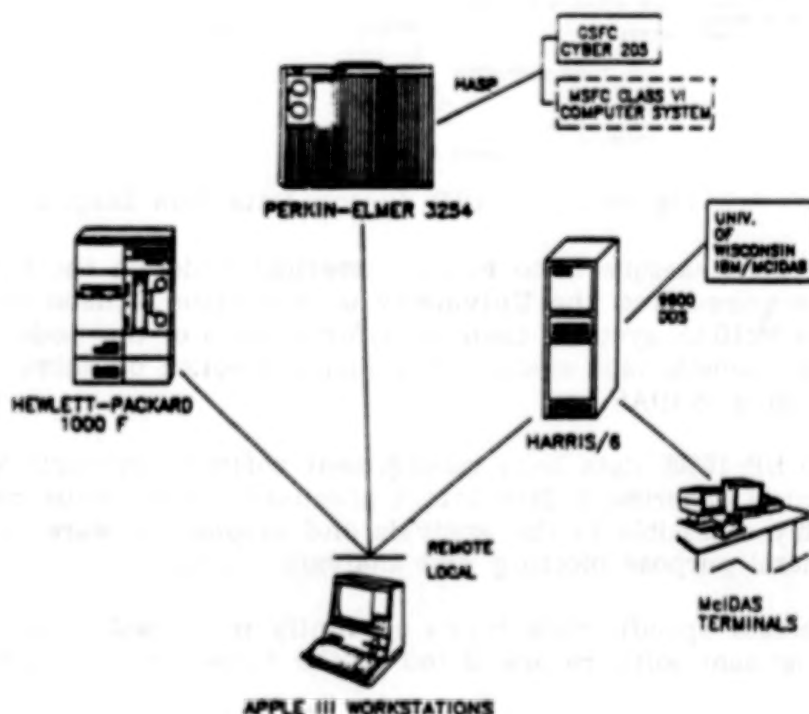


Figure 1-2. ASD Research Computer System.

2. DATA BASE MANAGEMENT CONCEPTS

As stated previously, each of the three minicomputers performs a specific function suited to its characteristics. Although the HP-1000F, Harris/6 and P-E systems are not directly connected to each other, it is mandatory that data move easily through the entire system in order to accomplish the required research. Figure 2-1 depicts overall data flow throughout the ASD system.

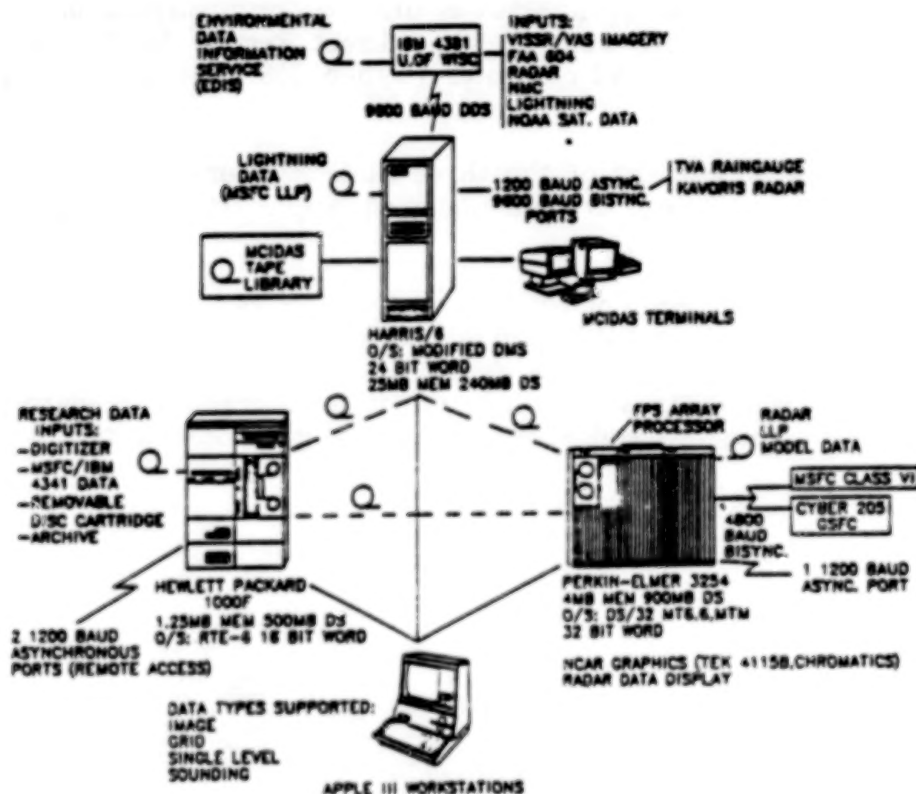


Figure 2-1. ASD System Data Flow Diagram.

A typical example is to run a numerical model on the P-E using a data file acquired from the University of Wisconsin-Madison McIDAS via the Harris/McIDAS system, then transfer results of the model to the Harris via magnetic tape media for visual inspection or animation by the scientist using McIDAS.

The HP-1000F data base management software converts various meteorological experiment data into a standard format, thus making the data readily accessible to the analysis and display software (AVE80) and other general purpose plotting and analysis packages.

The four specific data types currently processed utilizing the data base management software are listed in the following and shown in Figure 2-2:

- 1) Soundings (rawinsonde/satellite)
- 2) Single level (surface, cloud winds, LLP, precipitation, etc.)

- 3) Grids (from 1 and 2 above)
- 4) Image (satellite, radar).

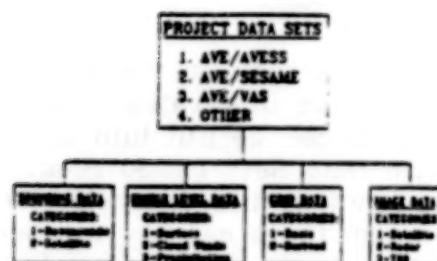


Figure 2-2. Data Base Management Software Data Types.

All data sets are initially converted into a "standard" format and a "random access" disk file created and named according to a defined data file naming convention. The data is stored on the HP-7933 400 MB disk which has been structured to provide simple file management. Each data set type is assigned to a specific logical unit:

- 1) LU#40 — 200 MB Image Data
- 2) LU#41 — 100 MB Grid Data
- 3) LU#42 — 50 MB Single Level
- 4) LU#43 — 500 MB Soundings.

The AVE80 analysis and display software expects the specific data types to exist on the assigned disk, along with a documentation file which describes the data base (number of times, stations, parameters, etc.) and a latitude/longitude file which provides the information for graphically plotting the station location, thus allowing for faster access while minimizing data housekeeping/archiving functions.

The four data types each have a dedicated "directory file" that contains the file names and parameter information for indexing into the "random access" data base. The number of stations, time periods, and data parameters are all provided in the directory file. The directory contains all data

sets currently existing "on-line" or "archived." Only the frequently accessed data files are kept "on-line" for processing interactively by the analysis and display software.

In summary, the HP-1000F data base management provides numerous utility programs which provide for the following:

- 1) Convert/create random access data base
- 2) Create/update directory file
- 3) Create documentation file
- 4) Create latitude/longitude file
- 5) Archive/restore data base

The Harris/6 offers the scientist a visual means of studying satellite, radar, or conventional data in an integrated manner. All of the data that comes into the McIDAS system can be put into one of three basic forms: images, grids, and "Station Data Set" (SDS) files. McIDAS images and grids are rather straight-forward, two-dimensional data structures. The SDS structure is one in which there are any number of measurements made at one location at a given time. A typical example is a set of surface reporting stations which records temperature, wind direction and speed, pressure reading, cloud cover, and several other parameters each hour, all associated with one location at the same time (Figure 2-3a). Nearly any non-continuous data types can be put into this format, with the beneficial result that it can be plotted, or contoured (via the grid structure) with the same software program as shown in Figure 2-3d.

Conventional balloon, surface, satellite temperature and moisture soundings (Figure 2-3c), and lightning strokes are examples of data that are put into SDS files. Radar data has been put into both the image and the grid format. Standard objective analysis software routines transform SDS data to the grid structure, usually for the contour drawing routine, but also for other research applications. The grids can then be put into an image format for display. Transformations in the reverse direction from the image structure to the other structures is usually done with a specialized research goal in mind, and algorithms are quite dependent upon the specific goal.

Although the P-E is primarily used for numerically-intensive processing, some files contain data types such as image and grid data. Work is currently underway to implement a data management method of handling these files, a using format similar to that of the HP to facilitate transportability between machines.

3. COMPUTER SYSTEM HARDWARE/SOFTWARE/COMMUNICATION

By offering data management and display as well as numerical modeling/number crunching capabilities, the ASD Research Computer System serves as a very useful interactive tool for the scientists. Brief specifications of each of the three computers in the ASD system are as follows:



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1) HP-1000F System (16-bit word) consists of 1.25 MB of main memory, 575 MB disk storage and operates under RTE-VI with session monitor and FORTRAN 66 compiler.

2) Harris/6 System (24-bit word) consists of 0.25 MB of main memory, 320 MB disk storage, and operates under modified DMS.

3) P-E 3250 System (32-bit word) consists of 8 MB of interleaved main memory, 900 MB disk storage and operates under OS/32 revision 6.2 with Multi-Terminal Monitor (MTM) and FORTRAN compilers D, O, and Z. A Floating Point Systems (FPS) AP-120B array processor is also attached to the P-E for off loading computer-bound jobs from the CPU.

Detailed hardware and configurations are shown in Figures 3-1, 3-2, and 3-3.

Remote interactive access to each of the ASD computers is provided by connection to a Develcon terminal switch via four dedicated 1200-baud asynchronous lines using standard RS-232 protocol. The HP-1000F system utilizes two of these lines to provide remote communications and to support both the XON/XOFF and ENQ/ACK protocols. The P-E and Harris/6 utilize the remaining two lines.

The Harris/6 system also has a DDS 9600-baud bisynchronous communication line with the IBM 4381 McIDAS at the University of Wisconsin, which provides access to real-time satellite images and the FAA "604" line data. For real-time support of ASD flight experiments, this line is used to put MSFC directly online as an IBM terminal. More commonly, the line is used as a computer to computer data link to transport "case study" data sets in

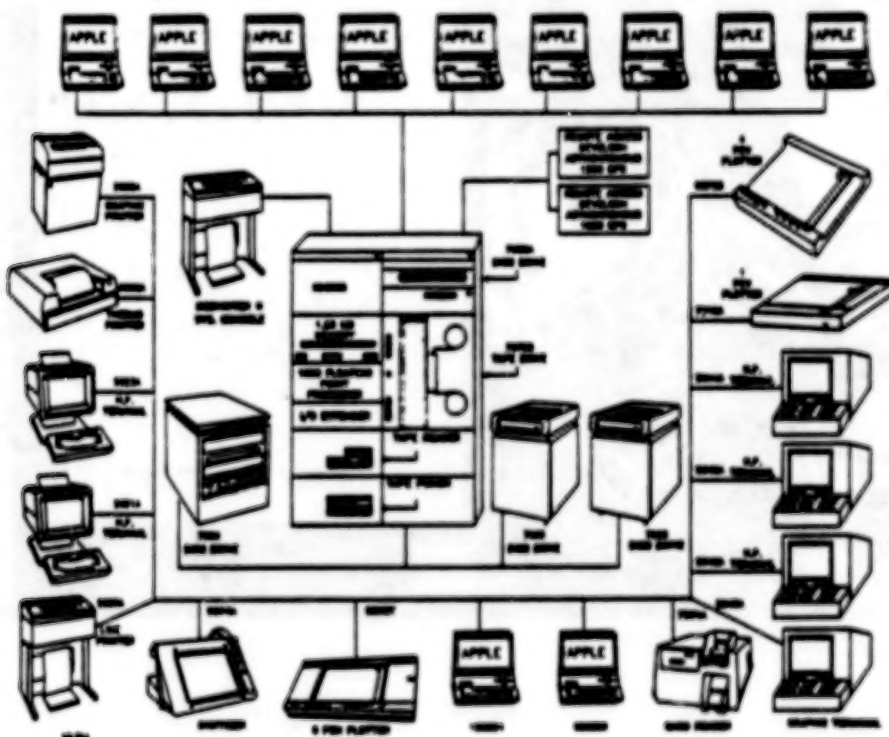


Figure 3-1. Hewlett Packard 1000F Computer System.

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a research mode. A special communication software package not only transfers the data, but formats it to be compatible with the SDS, GRID, and IMAGE data structures mentioned above. These digital files, as well as text data, can be transferred in either direction along the IBM 4381-Harris/6 McIDAS communication line.

Various hardcopy devices are available to document the scientist's work, both for general reference or for formal slide or overhead viewer presentations. The screen contents may be copied using either the Dunn Camera (8 x 10 Polaroid print or 35 mm slide) or the relatively inexpensive Honeywell black and white copier.

The Perkin-Elmer system offers an RJE connection via a 4800 baud bisynchronous modem driven by HASP protocol. Scientists currently utilize this link to access NASA's Cyber 205 located at Goddard Space Flight Center for running computer-intensive model code.

4. APPLICATION SOFTWARE

The HP-1000F computer system has a Data Management and Analysis System developed by Atsuko Computing International (ACI) which has been successfully implemented and utilized daily from the Apple III workstations by atmospheric scientists to graphically display and analyze large volumes of conventional and satellite derived meteorological data. By utilizing a Task Scheduler program (AVE80), as shown in Figure 4-1, the scientist can process various atmospheric data (sounding, single level grid, and image) interactively. The AVE80 program links approximately 30 software programs, allowing each to share common data and user inputs, thereby reducing overhead, optimizing execution time, and thus enhancing user capabilities. With the AVE80 programs, atmospheric data may be displayed in various forms such as station and parameter base map plots, skew t plots, vertical profiles of selected parameters, displayed images, parameter value printouts, and grid parameter contouring (Figures 4-2 through 4-5). The user selects the desired data parameters such as data type, set, category, group, and data base. Further, the user must select output type, output device, time period, pressure level, batch or non-batch mode, station number, latitude, longitude, colors, linestyles, and several additional options depending on the output desired.

Output devices available to the user include: HP plotters, HP graphics terminals, Apple III monitors, Apple Silentype printer, and an HP line printer/plotter.

The McIDAS terminals have large capabilities for displaying many types of data from various sources simultaneously. The MSFC researcher typically views a satellite image, with an overlaying graphics plot or contour of some other data type. Based on the combined information, the scientist will select an interesting portion of the image to work on and the procedure to use. Nearly any digitized image can be displayed on McIDAS, including images from most of the meteorological satellites. Since images can be viewed either individually or in animated sequences, a considerable amount of subjective and quantitative information is involved.

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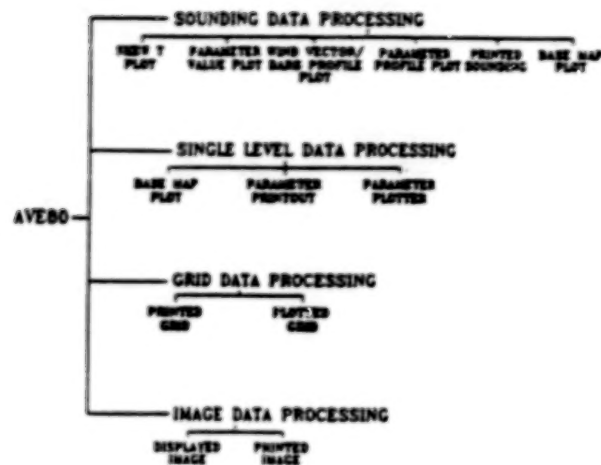


Figure 4-1. AVE80 Data Organization.

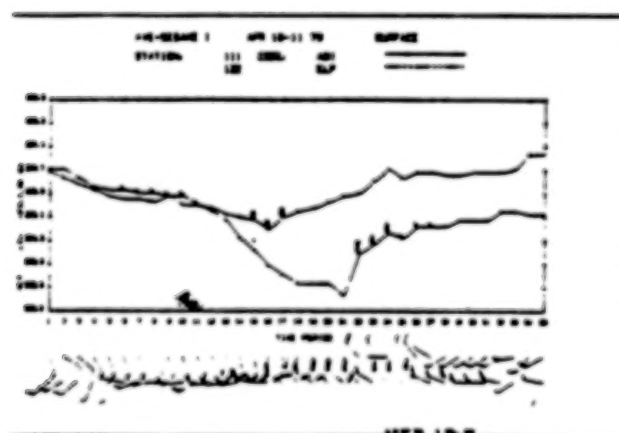


Figure 4-2. Parameter Plotter.

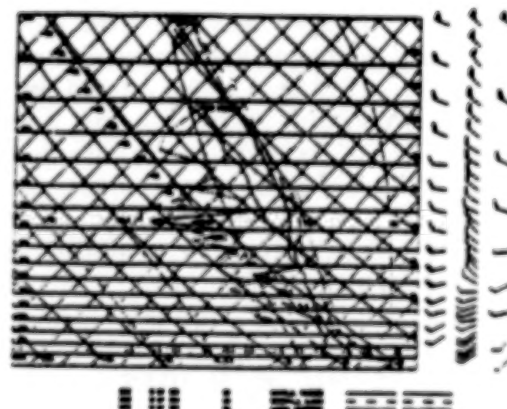


Figure 4-3. Skew t Plot.

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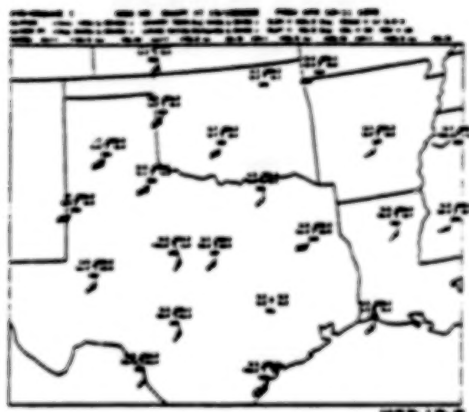


Figure 4-4. Base Map Plot from Sounding Data.

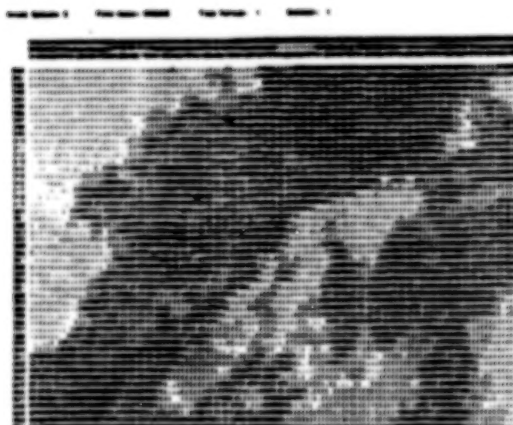


Figure 4-5. Printed Image.

The user may elect to display any desired meteorological satellite image or a sequence of images for animation purposes. These images can be enhanced in several ways (Figure 2-3b), both in color and black and white. Nearly an infinite selection of colors and combinations can be selected by the user via the keyboard, while the joystick provides a continuous control over brightness, color, intensity, image digital range, and contrast. The same range of colors is available to gradually "fade" graphics lines. Many different filter functions are available including high and low pass, gradient, edge preserving, and others, with more being added. Other features include stretching and other standard linear functions. Functions of several images can be done, including averaging, maximum and minimum values, and cloud cores. All data on McIDAS can be plotted or contoured,

with a large amount of user control over the appearance of resulting plots or contours. The size and colors of labels, and the placement of multiple SDS "station" parameters surrounding the actual station location are also user controlled.

Several high-level programs exist on McIDAS to permit application of sophisticated algorithms to image data. One such program uses many images at differing spectral wavelengths to reproduce vertical atmospheric temperature and moisture soundings. Another program uses several images in an animated sequence for the purpose of calculating cloud tracked winds. Calculation of standard statistical parameters and outputs of a histogram on any user selected portion of an image is accomplished by yet another image processing program between any two digital brightness values.

The P-E system currently has several scientific research models operational including LAMPS, Cloud Winds, Pielke's model and the South Dakota 2-D cloud model. NCAR graphics are supported with metacode translators for Tektronix terminals and the FR80 microfiche output. Plans exist to convert the translator to permit color graphics on the Tektronix 4115B.

5. INTERACTIVE SCIENTIFIC DATA PROCESSING (USER INTERFACE)

Four basic types of "user terminals" are integrated into the ASD system to allow the user/scientist to utilize the analysis and display software interactively to generate both color image displays and graphic outputs:

- 1) Apple III Workstations
- 2) McIDAS
- 3) Tektronix
- 4) Chromatics.

The Apple III workstations may be used as a standalone computer or selectively to access the capabilities of the HP-1000F, Harris/6 McIDAS, or P-E 3250 computers through communication lines. Software has been written which enables the Apple III to be used as an HP terminal including graphics capabilities. Future software will also allow the Apple III workstations to emulate the McIDAS terminal.

Currently, the Apple III terminal "workstations" have been integrated into the ASD computer system with the following capabilities:

- 1) Apple III with 256K bytes memory
- 2) Apple III Silentype Printer (Graphics Hardcopy)
- 3) One of the following monitors:
 - a) OMNI Panasonic Monitor TV
 - b) JVC Color Monitor

- c) BARCO Color Monitor
- d) High Resolution B&W Monitor
- 4) Novation 212A modem or equivalent (9600-baud communication)
- 5) 5 MB hard disk.

The Apple III terminals were chosen instead of conventional asynchronous terminals due to cost effectiveness, versatility, off-the-shelf availability and graphics and imaging quality.

Each McIDAS "terminal" consists of the keyboard and CRT echo monitor, the full "video" display, printer, joysticks, and a data tablet. This complete terminal costs approximately \$200,000. The video display monitor typically stores 16 different image and graphics "frames," with the capability for expansion by simple addition of a memory board. McIDAS users generally key in their command from a standard keyboard. Joysticks are used for movement of the cursor on the video screen to allow user interaction with the data. Also available is a "data tablet" and pen which allow the same cursor control and key-in capability with only one hand moving the special pen. All keys are programmable, which permits the user to simply strike the key of his choice to execute one of many commands. Alternatively, several options of a command may be stored, to be combined later with, each option represented by a single keystroke. The McIDAS "macro" capability allows a sequence of commands to be executed by keying in only the title of the sequence. The user has basic looping and decision-making capabilities in the execution of a list of commands in a macro. The above capabilities allow the scientists to pre-select a useful subset of McIDAS commands for his research, and simply touch the desired keys. This allows him to observe the results without having to spend valuable time making long key-ins.

The most powerful capability of McIDAS in the research mode lies in its ability to graphically overlay every other data type onto the satellite image projection. In this way, plotted or contoured measurements from the field can be visually related to the satellite images.

A Tektronix 4115B color graphics terminal with dual flexible disk drives, 10 MB Winchester hard disk, and 4691 color hardcopy unit is attached to the P-E for support of NCAR graphics. This terminal is also capable of running in standalone mode under CPM. FORTRAN and the IGL graphics package are also supported.

A Chromatics terminal is also used to produce color graphics output and interactive research on the P-E in support of Doppler Radar/Lidar research activities, specifically using NEXRAD software from NSSL.

6. SUMMARY AND CONCLUSIONS

In summary, the ASD Research Computing System currently provides the research scientist with the following capabilities:

1) An extensive Data Base Management package to convert various experiment data into standard formats for accessing by the general purpose plotting and data analysis packages.

2) An Analysis and Display package (AVE80) to graphically display and analyze large volumes of conventional and satellite derived meteorological data.

3) An interactive imaging/color graphics capability utilizing Apple III workstations integrated into the ASD computer system.

4) Local and remote smart-terminal capability which provides color video, graphics, and character display of the various data types.

5) A high speed minicomputer equipped with array processor for executing compute intensive code.

6) Tektronix 4115B and chromatics graphics terminals for high resolution.

7) Capability to overlay and analyze satellite imagery data and conventional meteorological data. Some image processing capabilities are also available.

8) Real-time and archive case study analysis of satellite, imagery and conventional data.

The systems continue to be upgraded to enable them to support future requirements as well as to enhance capabilities of the system to better meet the needs of the scientist/user. For example, the P-E is to be upgraded to an MPS system with multiple auxiliary processor units to better accommodate running simultaneous compute-bound jobs. Access to the proposed MSFC Class VI machine should also provide vast computational improvements by allowing access via Ethernet from each of the machines.

SENSOR STUDIES AND ANALYSES

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TITLE: Doppler Wind Profile Experiment

INVESTIGATOR: James E. Arnold
Atmospheric Sciences Division
Mail Code ED43
Marshall Space Flight Center, AL 35812

SIGNIFICANT ACCOMPLISHMENTS FOR FY-85:

The data collection phase of a Doppler wind measurement experiment supported by high-resolution Jimsphere/FPS-16 wind data and Windsonde data was carried out at the Kennedy Space Center in February, March and early April of 1985. The Doppler wind measurements were made using a hybrid NOAA/WPL Doppler profiler put in place by the Johnson Space Center and a SOUSY profiler operated by Radian Corporation. Both systems operated at 50 Mhz. Although the Doppler profiler systems were located 10 km apart to enable concurrent operation of the systems for data comparison, little concurrent data were obtained due to set-up delays with the SOUSY system, and system problems with the WPL system during the last month of the test.

During the test period, special serial Jimsphere soundings were taken at two-hour intervals on six days in March and April in addition to balloon soundings taken in support of the Shuttle launch operations. In addition, there is temperature, moisture and wind information available from the daily morning Radiosonde sounding taken at the Kennedy site. The balloon release point was at the same location as the SOUSY profiler. Vertical resolution of the SOUSY profiler was 150 M to approximately 20 km. The vertical resolution of the WPL profiler was 290 M to 10 km and 870 M to 17 km. Winds determined from the Jimsphere balloon have a vertical resolution of 30 M.

FOCUS OF CURRENT RESEARCH:

Comparisons between winds measured using high resolution balloon soundings (30 M vertical resolution and 0.5 m/s accuracy) and the Doppler wind profilers are currently underway. Experiments with the integration time over which the wind is being determined are being carried out with the SOUSY data. The WPL wind data is fixed at approximately a one hour integration period by the system software. The temporal variation of the wind also is being considered in the comparisons between the balloon wind soundings and the Profiler data.

PLANS FOR FY 84/85:

An evaluation of the Doppler wind profiling capability with respect to high vertical resolution, high temporal resolution and high accuracy balloon data (Jimsphere/FPS-16) will be carried out over the next few months. The data retrieval variability from the WPL profiler will be studied with respect to the synoptic conditions as reflected in the Rawinsonde data taken throughout the test. Applicability of both the WPL and SOUSY profilers to mesoscale studies will be explored based on both balloon and radar depictions of features in the wind profile.

TITLE: Multispectral Atmospheric Mapping Sensor of Mesoscale Water Vapor Features

INVESTIGATORS: Paul Menzel
1225 West Dayton Street
Madison, Wisconsin 53706
(608) 264-5325

Gary Jediovec
1225 West Dayton Street
Madison, Wisconsin 53706
(608) 262-0793

Greg Wilson
Atmospheric Sciences Division
Marshall Space Flight Center
Huntsville, Alabama 35812
(205) 453-2570

Robert Atkinson
Atmospheric Sciences Division
Marshall Space Flight Center
Huntsville, Alabama 35812
(205) 453-2570

William Smith
1225 West Dayton Street
Madison, Wisconsin 53706
(608) 263-4085

ACCOMPLISHMENTS:

The MAMS was checked out for specified spectral response and detector noise performance in the eight visible and three infrared (6.7, 11.2, 12.7 micron) spectral bands. A calibration algorithm was implemented for the infrared detectors. Engineering checkout flights on board the ER-2 produced imagery at 50 m resolution in which water vapor features in the 6.7 micron spectral band are most striking. These images were analyzed on the Man computer Interactive Data Access System (McIDAS). Ground truth and ancillary data (VAS, AVHRR) was accessed to verify the calibration.

CURRENT RESEARCH:

The MAMS is being flown over the Pre-Storm network during May 1985. MAMS will be used to measure at high spatial resolution the structure and variability of water vapor in the atmosphere in relation to development of cloud fields, precipitation, surface/boundary layer forcing, and sources/sinks of water vapor. MAMS observations will be amalgamated with data from the surface observational network (covering most of Oklahoma and Kansas at 50 km resolution), the rawinsonde sites (25 sites over Pre-Storm with three hourly launches), digitized NWS radars (seven sites), and

profilers (three sites). VAS and TOVS data will be used to corroborate MAMS data. Joint flights with the High resolution Interferometer Sounder (HIS) are planned in this time period. The single point high vertical resolution HIS sounding complements the high horizontal MAMS images; thus a merging of these data sources could provide three dimensional mesoscale data sets of high data density.

PLANS FOR FY-86:

Much of next year will be focused on data assimilation of the Pre-Storm case studies. MAMS-HIS data integration will be a large part of that work. In addition, some of the VAS data processing techniques will be attempted on the MAMS data. The two moisture channels on the MAMS will be used along with window radiance measurement to quantitatively derive estimates of atmospheric precipitable water values. The simultaneous physical retrieval method (Smith and Woolf, 1984) will be applied to MAMS measurements (with and without VAS and HIS radiances) in order to determine low layer moisture values from the split window imagery. Smith et al. (1985) have shown the usefulness of this technique with VAS data alone. The greatly increased horizontal resolution of MAMS radiance measurements over that of VAS will allow for the detection and estimation of precipitable water values at scales less than 10 km. Moisture fluctuations at this scale are believed to be an important factor in convective development.

REFERENCES:

Smith, W. L., and H. M. Woolf, 1984: Improved Vertical Soundings from an Amalgamation of Polar and Geostationary Radiance Observations. Preprints Conference on Satellite Meteorology/Remote Sensing and Applications, AMS, Boston, pp. 45-48.

Smith, W. L., G. S. Wade, and H. M. Woolf, 1985: Combined Atmospheric Sounding/Cloud Imagery - A New Forecast Tool. BAMS, Vol. 66, pp. 138-141.

TITLE: First Meeting of the Working Group on the Shuttle Microwave Precipitation Radiometer (SMPR)

HIGHLIGHTS:

This is a summary of the consensus of opinion of the working group, as well as selected comments attributable to certain participants.

The working group agreed that the first (primary) objective of such a Shuttle mission (instrument) should be the determination of methods for the accurate measurement of total rain water and total cloud water with passive microwave methods. There was no argument on the points concerning nonlinear relationships between T_B and rain rate (R) over the range of important rain rates (half of oceanic rainfall occurs at rates greater than 15 mm h^{-1}), such that variations in rain rate within a footprint lead to an incorrect measurement of the average rate for that footprint, and one cannot determine the characteristics of the sensed rain area. This is especially true near 18 GHz, where the dynamic range above 15 mm h^{-1} is very small because this frequency does not clearly fall in either a scattering regime or emissive regime at these wavelengths. It is also not clear whether very low frequency (emissive) techniques will be the best at measuring rain processes, or high frequency (scattering) techniques, where precipitation-size ice plays a major role in the signal attenuation. It is still not known what signal of rain is at certain rates on an observational basis because of the many different conditions that can exist within a single satellite observed footprint.

It was noted by the group that there is merit in the evaluation of global data with high resolution at frequencies between 6 and 200 GHz, with better than 5 km resolution when possible. The first priority in meeting the precipitation measurement objective was observations at approximately 6, 10, 18, 21, 37, and 90 GHz. A second priority was the inclusion of channels near the 50 GHz oxygen absorption band so that differencing could be employed to determine the vertical extent of precipitation. A third priority was the addition of water vapor information at the 183 GHz line to study cloud systems in general. Dr. William Smith (U. of Wisconsin) expressed the strongest interest in observing the precipitation and surrounding water vapor fields over a wide range of frequencies. Both he and Dr. Norman Grody (NOAA/NESDIS) agreed that the oxygen channel data might be very useful in determining the vertical extent of precipitation. Dr. Grody also expressed the opinion that the total vertically integrated rain water might be more useful (and easier) measurement than the rain rate at any particular level. Prof. James Weinman (U. of Wisconsin) felt that a radar would be a strong complement to a passive microwave instrument for also obtaining information on vertical distributions. Norm Grody felt an additional advantage of a radar would be to determine the relative merits of passive versus active systems for rainfall measurements. The group agreed that polarization information was important and so conical scanning was recommended. Bill Smith suggested that a sensor design study would be appropriate to determine the feasibility and costs involved in various instrumental configurations.

A second objective that the group felt was justified focused on gathering of information on rain systems from around the globe to calibrate visible and infrared techniques for rain measurement. Discussion on how this might be done ranged from cameras to digital multichannel imaging devices with stereo capability, but there was no single recommended instrument. It was felt, however, that in anticipation of future VIS/IR sensors with improved spatial resolutions the Shuttle instrument should have a commensurately high resolving power.

A third objective agreed to by the group was that of lightning detection relative to heavy rain associated with convection, as well as supporting science involving the electrification of clouds and updraft dynamics. No specific sensor was discussed.

At several points during the latter part of the meeting, Drs. Greg Wilson and Franklin Robertson (MSFC) pointed out that the group was advocating capabilities beyond what was originally intended to be discussed at the meeting, and amounted to the Shuttle Atmospheric Science Experiment (SASE) concept that the Atmospheric Sciences Division has been formulating for the previous 1-2 years.

SUMMARY AND MEETING RECOMMENDATIONS

The Space Shuttle was deemed a suitable platform for the gathering of information on the structure and characteristics of rain and cloud systems around the globe.

Objective

(ranked in order of importance)

- 1) The accurate measurement of total rain and cloud water
- 2) The calibration of VIS/IR methods for rainfall measurement
- 3) To provide supplementary information on the severity of convection, as well as address the electrification of clouds on a global basis.

Applicable Sensor

1st priority: 6, 10, 18, 22, 37, 90 GHz
2nd priority: 50-55 GHz channels
3rd priority: 183 GHz channels

VIS/IR TBD

Lightning Sensor TBD

APPENDIX A. AUTHORS

1. Achtemeier, Gary
2. Anderson, C. E.
3. Arnold, James
4. Arnold, Roy
5. Atkinson, Robert
6. Auvine, Brian
7. Bilbro, J. W.
8. Blakeslee, Richard
9. Bowdle, David
10. Brook, Marx
11. Carroll, John
12. Christian, Hugh
13. Clark, John
14. Diak, George
15. Dickerson, Michael
16. Dutton, John
17. Emmitt, G. D.
18. Fitzjarrald, D. R.
19. Fowles, William
20. Fuelberg, Henry
21. Fujita, T. T.
22. Goodman, Steven
23. Greene, William
24. Hansen, Anthony
25. Hart, John
26. Hathaway, David
27. Hayden, Christopher
28. Hibbard, Bill
29. Hickey, John
30. Houghton, David
31. Howland, Michael
32. Hung, R. J.
33. Jedlovec, Gary
34. Johnson, Donald
35. Johnson, R. L.
36. Kalb, Michael
37. Karitani, Shogo
38. Keller, David
39. Kidder, Stanley
40. Kopecky, Kenneth
41. Kopp, Fred
42. Krauss, Robert
43. Krider, E. Philip
44. Leslie, Fred
45. Martin, David
46. Menzel, Paul
47. Miller, Timothy
48. MacGorman, Donald
49. MacLean, Laura
50. McQuirk, James
51. McNider, Richard
52. Nagle, Richard
53. Ochs, Harry T.
54. Parker, Karen
55. Perkey, D. J.
56. Purdom, James
57. Reavis, Norman
58. Reynolds, Nathaniel
59. Roberts, Glyn O.
60. Robertson, Franklin
61. Rothermel, Jeffry
62. Rust, W. David
63. Saltzman, Barry
64. Schlesinger, Robert
65. Shirer, Hampton
66. Smith, Phillip
67. Smith, R. E.
68. Smith, William
69. Spencer, Roy
70. Soumi, Verner
71. Tang, C.
72. Thompson, Aylmer
73. Toomre, Juri
74. Vaughan, O. H.
75. Vincent, Dayton
76. Vonder Haar, Thomas
77. West, G. S.
78. Williams, Steven
79. Wilson, G. S.
80. Young, J. T.

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APPENDIX B. ORGANIZATIONS WHOSE SPONSORED RESEARCH
EFFORTS ARE INCLUDED IN THE FY-85 ATMOSPHERIC
PROCESSES RESEARCH PROGRAM REVIEW

1. Atsuko Computing International
2. Colorado State University
3. Drake University
4. Drexel University
5. General Electric Company
6. Illinois State Water Survey
7. Marshall Space Flight Center Systems Dynamics Laboratory
8. Marshall Space Flight Center Space Science Laboratory
9. New Mexico Institute of Mining and Technology
10. New Technology, Inc.
11. NOAA/National Severe Storms Laboratory
12. Purdue University
13. Roberts Associates, Inc.
14. Saint Louis University
15. Simpson Weather Associates, Inc.
16. South Dakota School of Mines
17. Southwest Research Institute
18. State University of New York at Albany
19. Texas A&M University
20. The Pennsylvania State University
21. The University of Alabama in Huntsville
22. University of Arizona
23. University of California
24. University of Chicago
25. University of Colorado
26. University of Mississippi
27. University of Wisconsin
28. Universities Space Research Association
29. Yale University

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16. ABSTRACT A review of the NASA/MSFC FY-85 Atmospheric Processes Research Program was held in Huntsville, Alabama, May 7-9, 1985 and Columbia, MD, July 8-12, 1985. The review covered research tasks sponsored by the NASA Office of Space Science and Applications, Earth Sciences and Applications Division, in the areas of global scale and mesoscale processes. The two main areas of focus for NASA/MSFC's Atmospheric Research Program are: (1) Global Scale Processes (Geophysical Fluid Processes, Satellite Doppler Lidar Wind Profiler, and Satellite Data Analyses); and (2) Mesoscale Processes [Atmospheric Electricity (Lightning), Ground/Airborne Doppler Lidar Wind Measurements, and Mesoscale Analyses and Space Sensors]. This report contains the research project summaries, in narrative outline, supplied by the individual investigators.			
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